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It is concluded that polyester reinforcement is undesirable for bearing pads much over one inch in thickness because of its relative flexibility and tendency to creep substantially under sustained loads. Compressive stress/strain data is presented for pads with shape factors up to 15.0. Shear modulus data is presented for various sizes of pads and angles of translation. Data from creep and cycling tests simulating dead load and live load conditions demonstrate the desirability of steel or fiberglass reinforced pads.

The report includes recommended design data, current California specifications for bearing pads, and suggestions for further research.



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# HIGHWAY RESEARCH REPORT

# A LABORATORY EVALUATION OF FULL SIZE ELASTOMERIC BRIDGE BEARING PADS

## FINAL REPORT

74-26


STATE OF CALIFORNIA

BUSINESS AND TRANSPORTATION AGENCY

DEPARTMENT OF TRANSPORTATION

DIVISION OF HIGHWAYS



TRANSPORTATION LABORATORY


RESEARCH REPORT


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RONALD REAGAN, *Governor*

DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
TRANSPORTATION LABORATORY
5900 FOLSOM BLVD., SACRAMENTO 95819

June 1974

Translab No. 636574
Item D-4-95

Mr. R. J. Datel
State Highway Engineer

Dear Sir:

Submitted herewith is a final research report titled:

A LABORATORY EVALUATION

OF FULL SIZE

ELASTOMERIC BRIDGE BEARING PADS

Author and Co-Principal Investigator
W. F. Crozier, P. E.

Principal Investigator
J. R. Stoker, P. E.

Principal Assistant
V. C. Martin

Under the Supervision of
E. F. Nordlin, P. E.

Very truly yours,

JOHN L. BEATON
Chief Engineer, Transportation Laboratory

## ACKNOWLEDGEMENTS

This research was accomplished in cooperation with the United States Department of Transportation, Federal Highway Administration, as Item D-4-95 of work program HPR-PR-1(8), Part 2, Research, and was titled "Elastomeric Bridge Bearing Pads". The contents of this report reflect the views of the Transportation Laboratory which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

The authors wish to express their appreciation for the able assistance provided by the following staff members of the Transportation Laboratory in the conduct of this test program:

| | |
|---|---|
| Robert S. Ferwerda | Project Planning and Coordination |
| Richard L. Blunden | Fixture Design and Data Reduction |
| Floyd E. Martin | Fabrication of Test Fixtures |
| Walter N. Richards | Operation of Testing Machine |
| J. Jay Folsom | Technical Consultation |

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# I. INTRODUCTION

Elastomeric pads were first used as bridge bearings in the United States in the late 1950's largely due to the need to find a satisfactory bearing device to accommodate the relatively severe end rotation and translation associated with prestressed concrete structures and to utilize a more economical and maintenance free bearing concept than those used previously. At that time the State of California initiated a research project titled "Laboratory and Field Performance of Elastomeric Bridge Bearing Pads"[1] to establish design guidelines and specifications for these pads. That study revealed that neoprene pads reinforced at 1/2 inch intervals with steel sheet or polyester fabric performed very satisfactorily in the bridges constructed during that period. The polyester fabric became the most commonly used reinforcement in California since it was less expensive than the steel because large pads could be fabricated, stockpiled, and, then, sliced into custom sizes upon demand. Steel reinforced pads must be individually fabricated to the desired size because of the necessity to cover the edges of the steel with elastomer for corrosion protection.

During the 1960's the use of prestressed concrete bridges became more common and typical span lengths became longer due to the designer's interest in economy, safety, and aesthetics. Consequently, the bearing pads became larger in both plan area and thickness to accommodate the increased loads, translations, and rotations. As pad sizes increased, construction personnel began to notice pad deflections that were considerably different than those anticipated. At that time pad deflections were predicted on the basis of tests performed on relatively small pads. Design data such as that published by E. I. duPont de Nemours and Company[2] was extrapolated to estimate the behavior of the pads being used. When it became apparent that extrapolation of data from small pads would not assure satisfactory performance of large pads, this research project was initiated to evaluate the physical characteristics of full size bearing pads, and to modify the pertinent specifications and design criteria if necessary.

The objective of this research was to evaluate the performance of full size bearing pads under test conditions which simulate the physical environment they are subjected to in actual field use. Various shapes and sizes of pads up to seven square feet in plan area and 5 inches in thickness were subjected to compressive, cycling, creep, translation, rotation, and ultimate strength tests. Typical pads consisted of 55 durometer neoprene reinforced at 1/2 inch intervals with steel, polyester, or fiberglass reinforcement.

## II. CONCLUSIONS

The following conclusions apply to pads fabricated in accordance with the California specifications presented in the Appendix. Among the requirements of these specifications are: 55 ± 5 durometer hardness (ASTM D1149, Type A); reinforcement at 1/2 ± 1/8 inch intervals; 20 gage mild steel reinforcement or fabric reinforcement possessing a minimum ultimate tensile strength of 700 pounds per inch at top and bottom of pad and 1400 pounds per inch within the pad.

### Polyester Reinforced Pads

1. The compressive deflection of polyester reinforced pads is difficult to predict accurately because:

   a. The magnitude of deflections is much greater than that of steel or fiberglass reinforced pads because of the relative flexibility of the polyester fabric.

   b. The compressive stiffness decreases as the overall pad thickness increases.

   c. The compressive creep under sustained dead load stresses is two to three times that of steel or fiberglass reinforced pads because of the creep of the polyester fabric.

   d. Compressive deflections due to live load cycling tend to remain in the pad after the live load is removed.

2. The translation and ultimate strength properties of polyester reinforced pads are very similar to those of fiberglass reinforced pads.

### Fiberglass Reinforced and Steel Reinforced Pads

1. The compressive deflections of fiberglass or steel reinforced pads can be reliably predicted within the normal range of construction tolerances.

2. The compressive stiffness of fiberglass or steel reinforced pads is not significantly dependent on the overall pad thickness.

3. The compressive creep of fiberglass or steel reinforced pads under sustained dead load stresses is approximately 25 percent of initial deflection after ten years of service.

4. Compressive deflections of fiberglass or steel reinforced pads due to live load cycling tend to diminish after the live load is removed.

5. The ultimate compressive strength of fiberglass or steel reinforced pads is more than 1600 psi. The mode of failure is fabric tearing or steel yielding.

6. Under a nominal compressive load of 800 psi, fiberglass or steel reinforced pads may be subjected to rotational forces until the compressive strain at an extreme edge is zero without damaging the pad.

7. The shear modulus of fiberglass or steel reinforced pads is approximately 100 psi at 70°F. This value is not significantly dependent on pad size, shape, skew angle, or compressive stress.

## III. RECOMMENDATIONS AND IMPLEMENTATION

1. Polyester reinforced pads over one-inch in thickness should not be used in bridge bearings because of the difficulty in predicting compressive deflection.

2. For pad thicknesses normally used in bridge construction, steel or fiberglass reinforced pads should be specified in accordance with the specifications presented in the Appendix.

3. Compressive deflections for steel or fiberglass reinforced pads should be predicted using Figure 1. The accuracy of these curves is considered to be well within the range of normal construction tolerances. If long term compressive creep is to be included in the prediction, the values obtained from Figure 1 should be increased by 25 percent. For special situations where extreme accuracy is desired, sample pads should be tested to determine the stress/strain behavior of each lot of pads.

4. Further research is needed to improve specifications and test methods used to assure the quality of bridge bearing pads. Based on field performance to date, current specifications and test methods result in high quality pads, but these requirements vary considerably throughout the nation; some tests are difficult and/or expensive to perform; and, in some cases, the requirements may be unnecessarily conservative and restrictive. Research is needed to develop simple, inexpensive test methods which are related to performance requirements.

5. If further research is contemplated for large bearing pads, careful consideration must be given to test method details. Recommendations regarding such details are included in the Appendix.

Recommendations 1 and 2 were implemented by the California Department of Transportation, CALTRANS, in late 1972 by way of a Standard Special Provision. Since that time, there have been no reports of adverse performance of fiberglass reinforced pads. Recommendation 3 has not yet been formally implemented but is expected to be adopted as standard design data by the Office of Structures of CALTRANS.

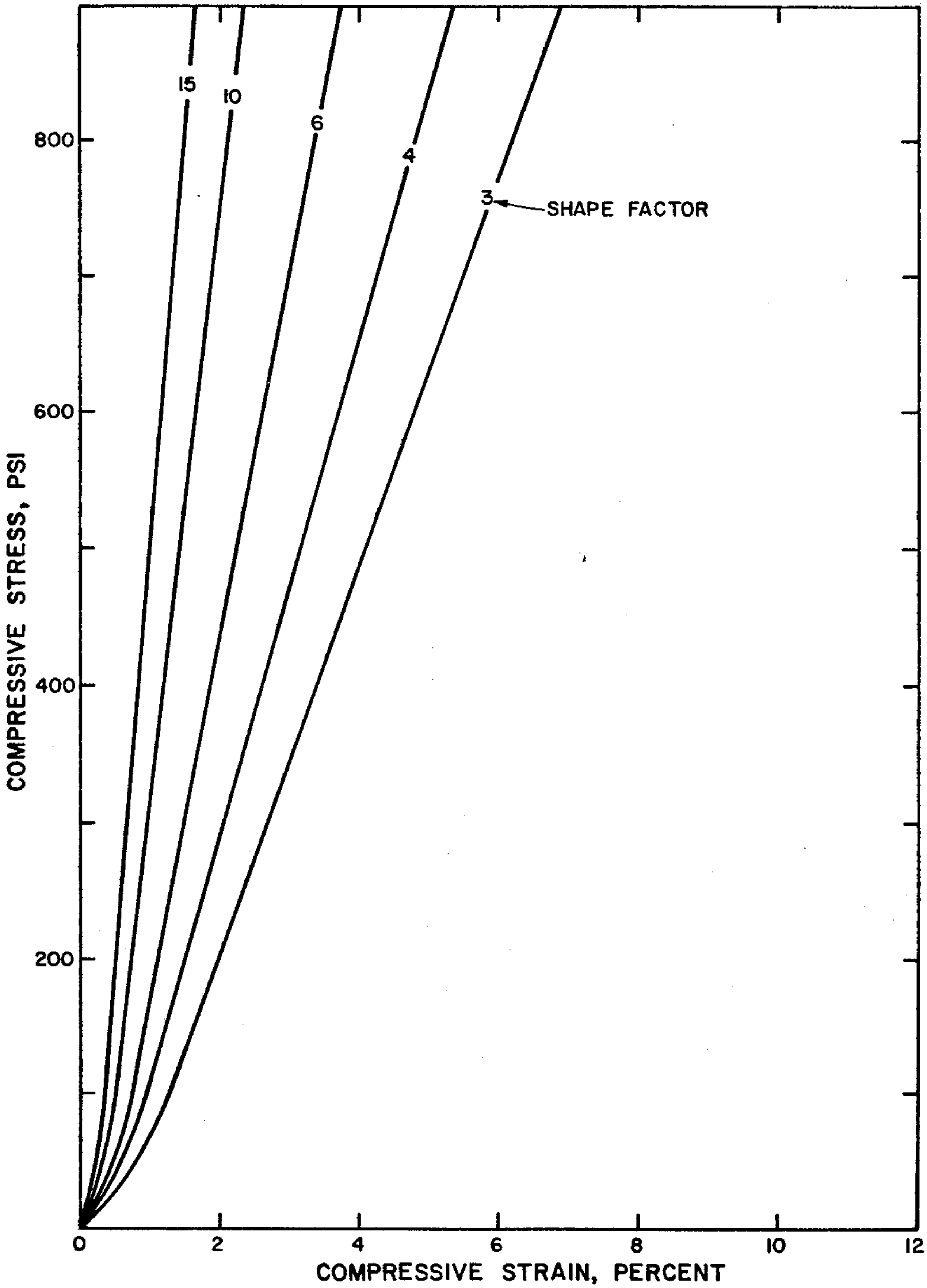



**Fig. 1 RECOMMENDED COMPRESSIVE STRESS/STRAIN CURVES FOR STEEL OR FIBERGLASS REINFORCED PAD, 55 DUROMETER NEOPRENE**

# IV. TECHNICAL DISCUSSION

## A. General Discussion of Testing Program

The basic objective of this research was to evaluate the physical characteristics of elastomeric bridge bearing pads commonly used in highway construction under loading conditions which simulate their in-service environment. The overall pad dimensions were selected to represent the range of sizes to be expected in modern bridge construction. Pads were purchased out of production runs from several manufacturers, and complied with all the specifications presented in the Appendix which substantially effect the physical properties.

The material properties which were most pertinent to the physical properties are listed below:

1. The sole polymer in the elastomeric compound was neoprene and said polymer was at least 60 percent by volume of the total compound.

2. The Shore durometer hardness (Type A) was 55 $\pm$ 5.

3. The reinforcement was at 1/2 $\pm$ 1/8 inch intervals.

4. The steel reinforcement was 20 gage mild steel.

5. The fabric reinforcement was single ply at the top and bottom surfaces of the pads, and double ply within the pads.

6. Each ply of fabric reinforcement possessed a breaking strength of at least 700 pounds per inch.

Early in the testing program only pads reinforced with steel or polyester fabric were tested. A great majority of the tests were performed on polyester reinforced pads since this type of pad had been blamed for problems involving excessive deflection which occurred during bridge construction. As testing progressed, it became increasingly clear that polyester fabric was not a satisfactory reinforcement material for pads more than one inch or so thick. Fiberglass fabric was then substituted for the polyester fabric in hopes of finding a reinforcing fabric stiffer and more creep resistant than polyester. Subsequent testing demonstrated that fiberglass fabric is much more desirable than polyester fabric for reinforcing bridge bearing pads over one-inch thick.

Although the polyester reinforced pads represent the majority of test specimens for this project, the presentation of data herein for polyester reinforced pads is limited to typical data which illustrate the variation in physical properties between polyester, fiberglass, and steel reinforced pads. Data from tests on steel and fiberglass reinforced pads are presented in more detail since these types of pads are expected to be used in the future.

In presenting data in this report, the test pads are identified by pad numbers such as 73-621A. These numbers bear no significance other than to identify individual pads by a standard laboratory sample identification numbering system. For the reader who is interested in more detailed information on any particular test pad, the pad details are listed in the Appendix. All tests were run at a temperature of approximately 70°F.

B. Compressive Stress/Strain Behavior

1. Test Procedure

Accurate prediction of the deflection of a bearing pad under compressive loads is necessary in order to assure that the bridge deck elevations on either side of an expansion joint will match within reasonable tolerance. Therefore, a large number of compressive tests were performed on pads with various reinforcement, overall dimensions, and shape factor to determine the compressive stress/strain behavior.

Shape factor is a commonly used parameter which is used to predict compressive stress/strain behavior and is defined as the loaded area divided by the total free area[2,3]. In other words, for a pad of width, w, length, l, and distance between layers of reinforcement, t, the shape factor, sf, would be:

$$sf = \frac{wl}{2t(w+l)}$$

Compressive stress/strain tests were performed on pads possessing shape factors from about 3 to 15. In order to minimize the cost of purchasing pads, larger pads were first tested and then cut into smaller pads for subsequent tests. The typical testing and cutting sequence is illustrated in Figure 2. One disadvantage to this type of testing sequence is that previous loading history may affect a pad's stress/strain behavior in subsequent tests, particularly for those pads which tend to creep under compressive load. To combat this problem, testing was minimized on pads which were to be cut into smaller pads, and a minimum of 16 hours was allowed between tests for the pad to recover from any permanent set. To assess the effect of previous loading, several pads were subjected to repeat tests and it was concluded that a few cycles of loading do not significantly effect the stress/strain behavior of steel or fiberglass reinforced pads.

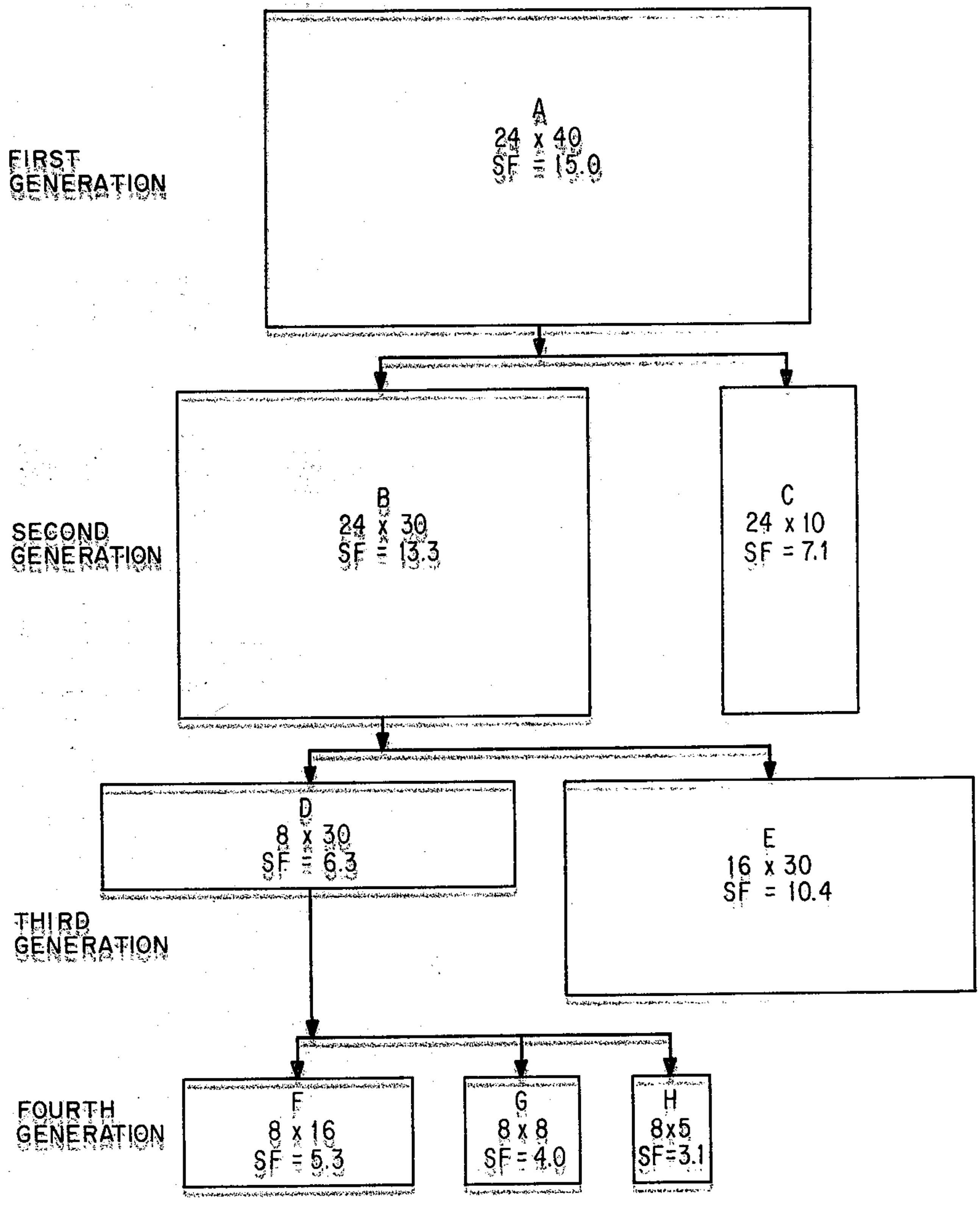
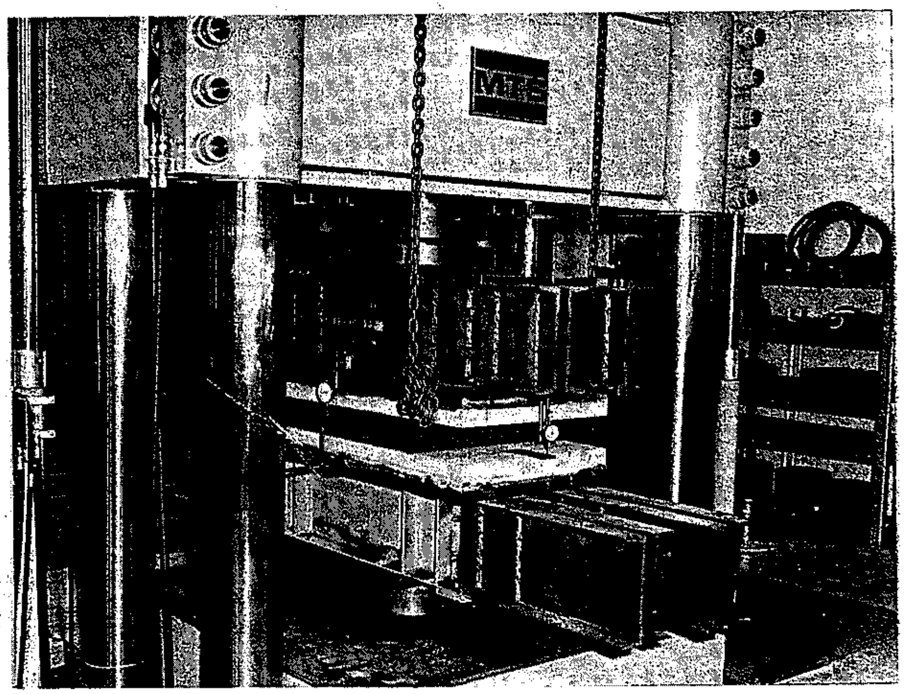



Figure 2, TYPICAL SEQUENCE OF COMPRESSIVE TESTS

Figure 3 illustrates the test set-up for pads whose greatest dimension was larger than 24 inches. For these large pads the C12x30 steel channels were needed to distribute the load uniformly to the pad. The composite concrete and steel plates shown in Figure 3 were fabricated to provide a relatively rigid bearing against the test pads while simulating the frictional characteristics between concrete and pads in an actual installation. The concrete was heavily reinforced and attached to the steel plates by shear connectors. The simulation of frictional characteristics was important for the translation tests which are discussed in Section IV. G., but test results showed that the difference between concrete versus steel bearing surfaces in compression tests was not significant. For pads whose greatest dimension was less than 24 inches, the channels were removed to simplify the test set-up. For pads whose greatest dimension was less than 18 inches the 24 by 48 inch concrete and steel plates were also removed from the test set-up. The testing machine used in all tests was a 1,000,000 pound capacity, electrohydraulic, universal testing machine with a remote console for programming loading schedules.

For pads whose greatest dimension was less than 10 inches, deflections were measured by a linear variable differential transformer which is an integral part of the testing machine. For larger pads, deflection was measured by a minimum of four dial gages, reading to the nearest 0.001 inch, located generally as shown in Figure 3. The data presented herein represents the data obtained from the two dial gages located nearest the center of the pad. The data obtained from the gages located near the ends of the concrete and steel plates is not presented since it is not considered representative of pad deflection. This subject is discussed in greater detail in the Appendix.

The compressive load was increased at a rate of 200 psi per minute but the load was held constant at increments in order to allow time to read deflections. The deflections were read quickly, within one minute, in order to minimize the effect of creep on the deflection readings. Deflections were typically read at several intervals up to 100 psi and then at intervals of 100 psi for the remainder of the test as illustrated in Figure 4. The smaller intervals were used to define the lower portion of the stress/strain curve, particularly to define the point of zero stress and zero strain. To establish this zero point, the slope of the stress/strain curve between the two lowest stress levels, normally 10 and 20 psi, was projected downward to zero stress with the resulting point considered zero strain. This technique provided an objective method for establishing the zero point while inducing a minimal amount of error into the stress/strain curves.



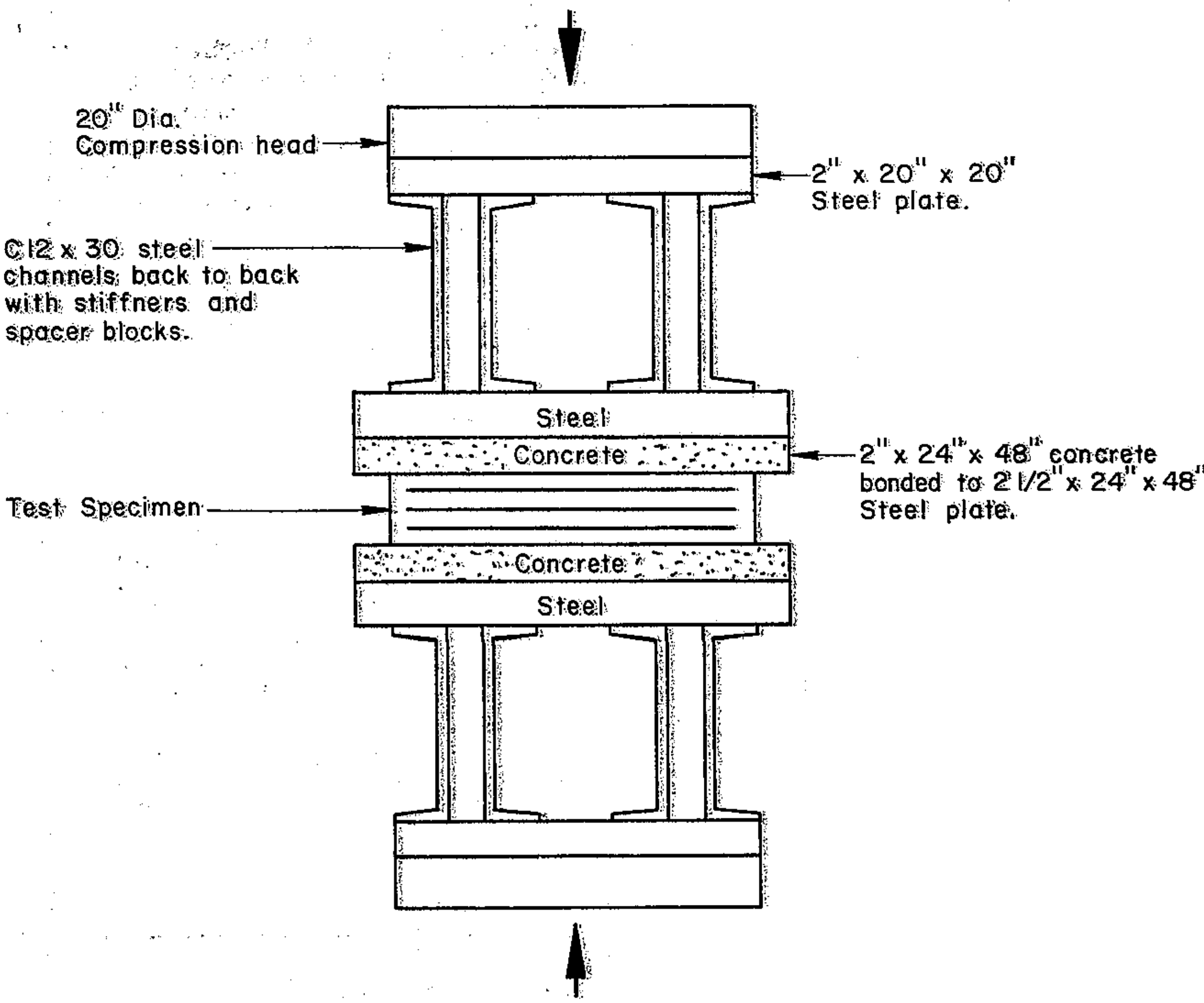



Figure 3 TYPICAL COMPRESSION TEST APPARATUS

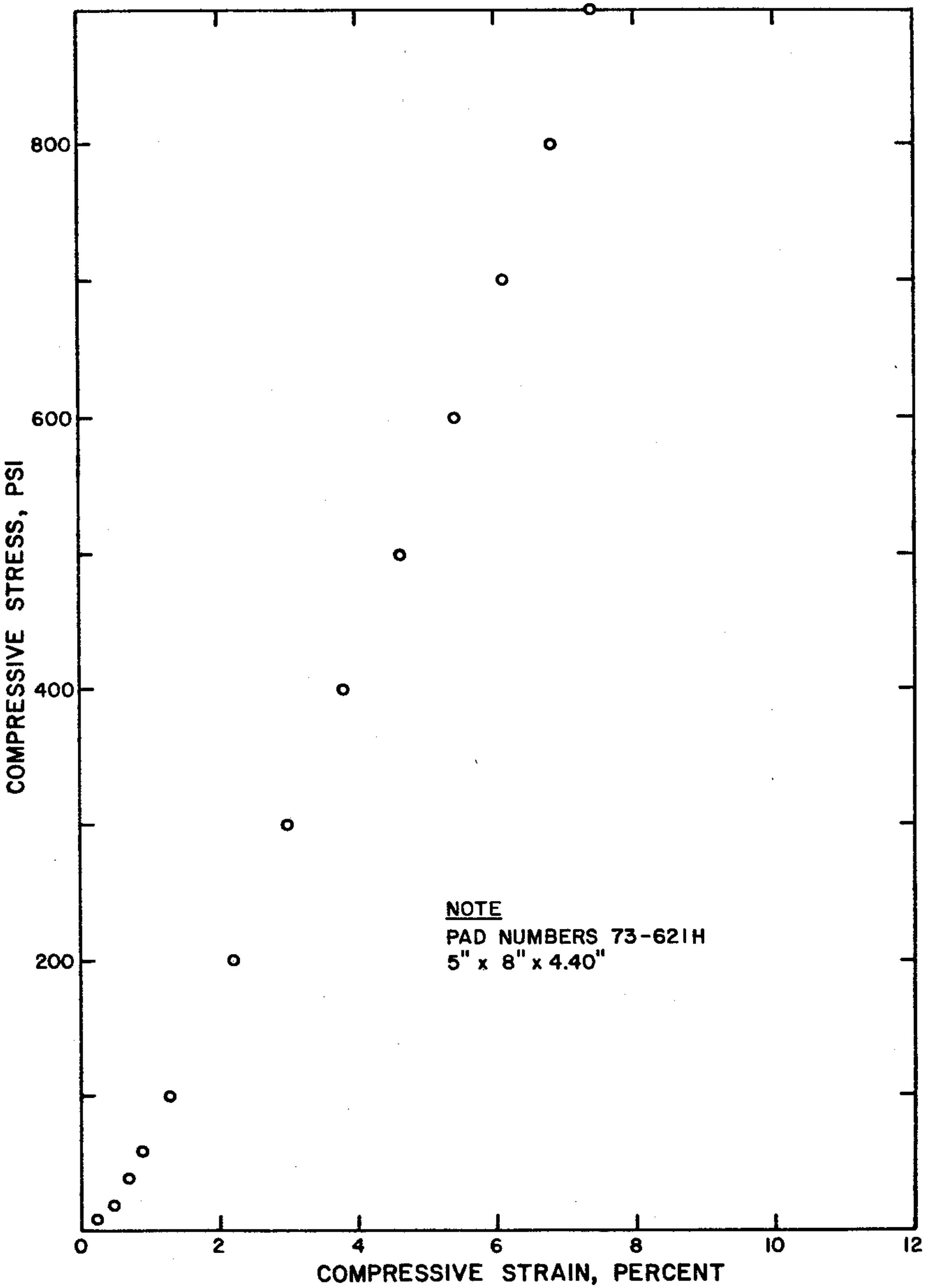



Fig. 4 TYPICAL DATA POINTS FOR COMPRESSIVE STRESS/STRAIN CURVE

In computing strains from the deflection data, the overall pad thickness was used which included the thickness of the reinforcement. In computing shape factors the nominal center-to-center distance between the layers of reinforcement was used.

2. Test Results

Figures 5 and 6 illustrate the substantial difference between the compressive stress/strain characteristics of polyester reinforced pads versus steel or fiberglass reinforced pads. Regardless of shape factor or stress level, the polyester reinforced pads undergo far more strain than equivalent steel or fiberglass reinforced pads. This characteristic makes them less desirable than steel or fiberglass reinforced pads when a relatively thick pad is needed for an expansion joint. Because of their relative flexibility, variations in dead load or the pad's stress/strain curve from that expected can yield relatively large unexpected deflections.

Figures 7 and 8 present the compressive stress/strain curves obtained from steel and fiberglass reinforced pads with shape factors ranging from 3 to 15. Regardless of shape factor, the compressive stress/strain characteristics of fiberglass reinforced pads are very similar to steel reinforced pads up to compressive stress levels of 1000 psi. Under these stress conditions the tensile stiffness of the fiberglass fabric is comparable to the 20 gage steel sheet.

3. Development of Recommended Stress/Strain Curves

In order to convert the data such as that shown in Figures 7 and 8 into usable form for design purposes, a technique employed by the Battelle researchers was selected[3]. At various compressive stress levels, the values of compressive strain are plotted versus shape factor on a log-log plot. Straight lines are fitted to this data and appropriate values from these straight lines are plotted to establish stress versus strain curves for various shape factors. Figures 9 and 10 illustrate the compressive strain versus shape factor curves at 800 and 200 psi. The straight lines in these figures were used with others at other stress levels to establish the recommended stress/strain curves of Figure 1.

By studying Figures 9 and 10 one can see that the steel reinforced pads tend to be slightly stiffer in compression than fiberglass reinforced pads but not substantially stiffer. Therefore, to simplify design procedures, a single set of compressive stress/strain curves are recommended to represent both steel and fiberglass reinforced pads.

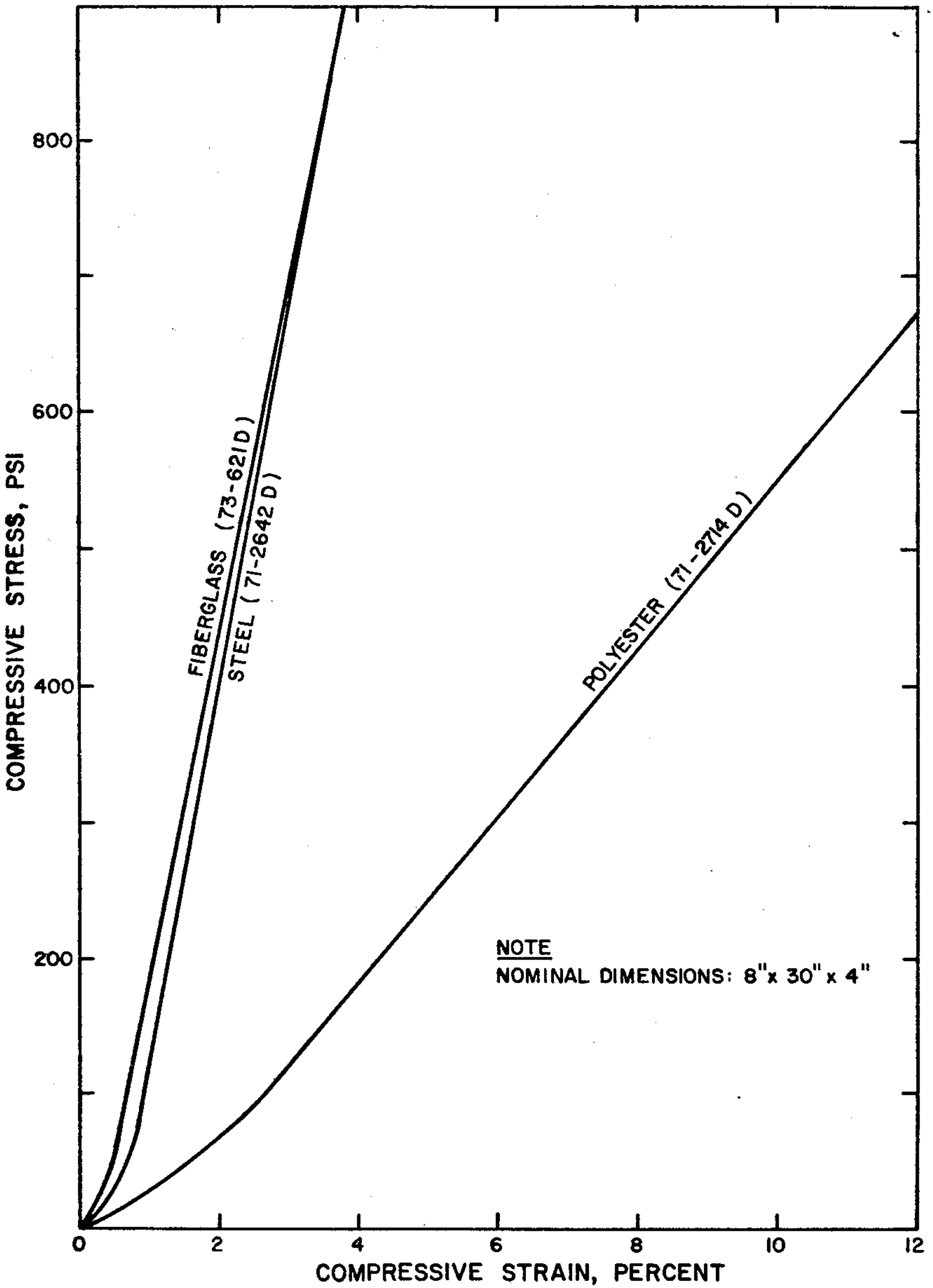



**Fig. 5 STRESS VS. STRAIN WITH VARIOUS REINFORCEMENT, SHAPE FACTOR=6**

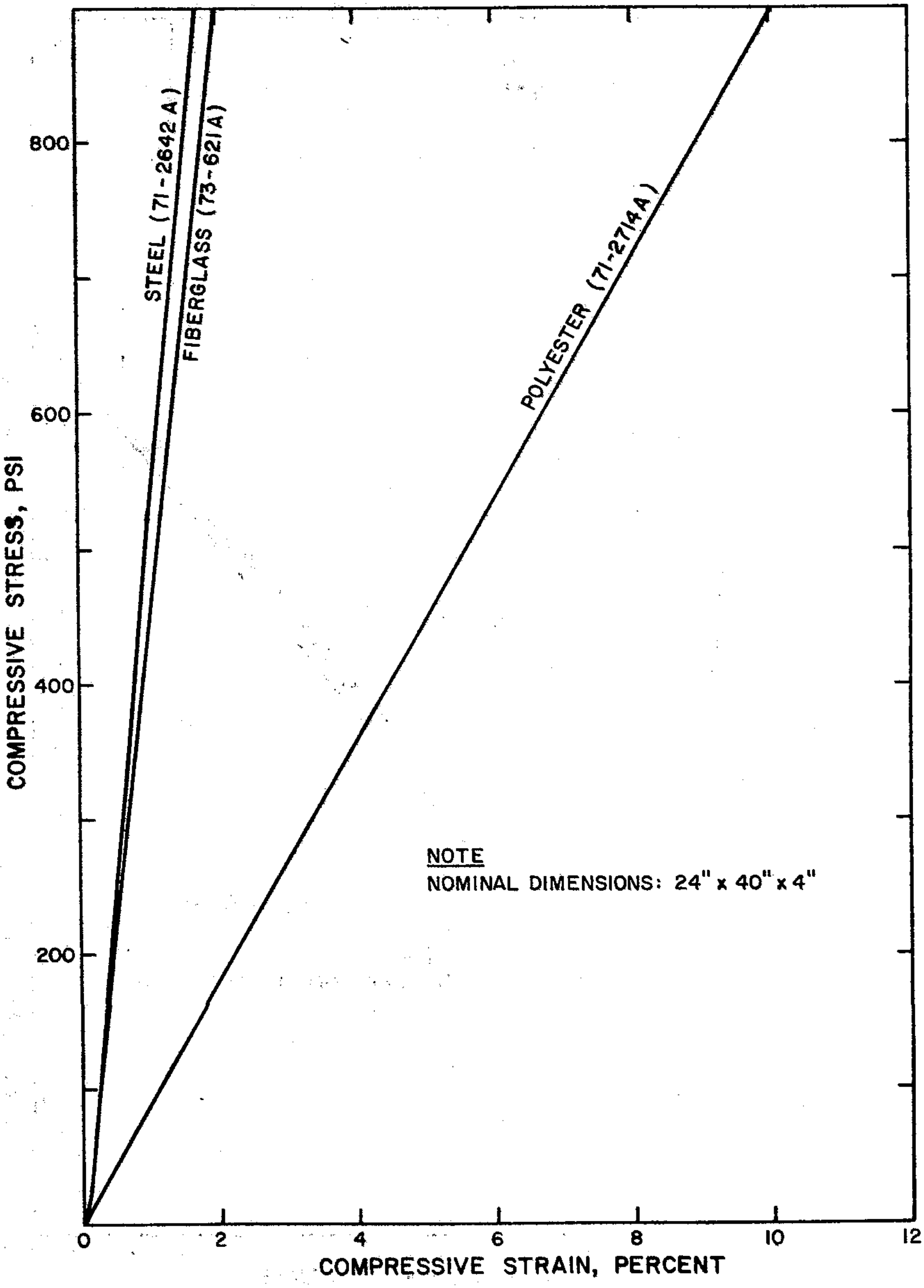



Fig.6 STRESS VS. STRAIN WITH VARIOUS REINFORCEMENT, SHAPE FACTOR = 15.0

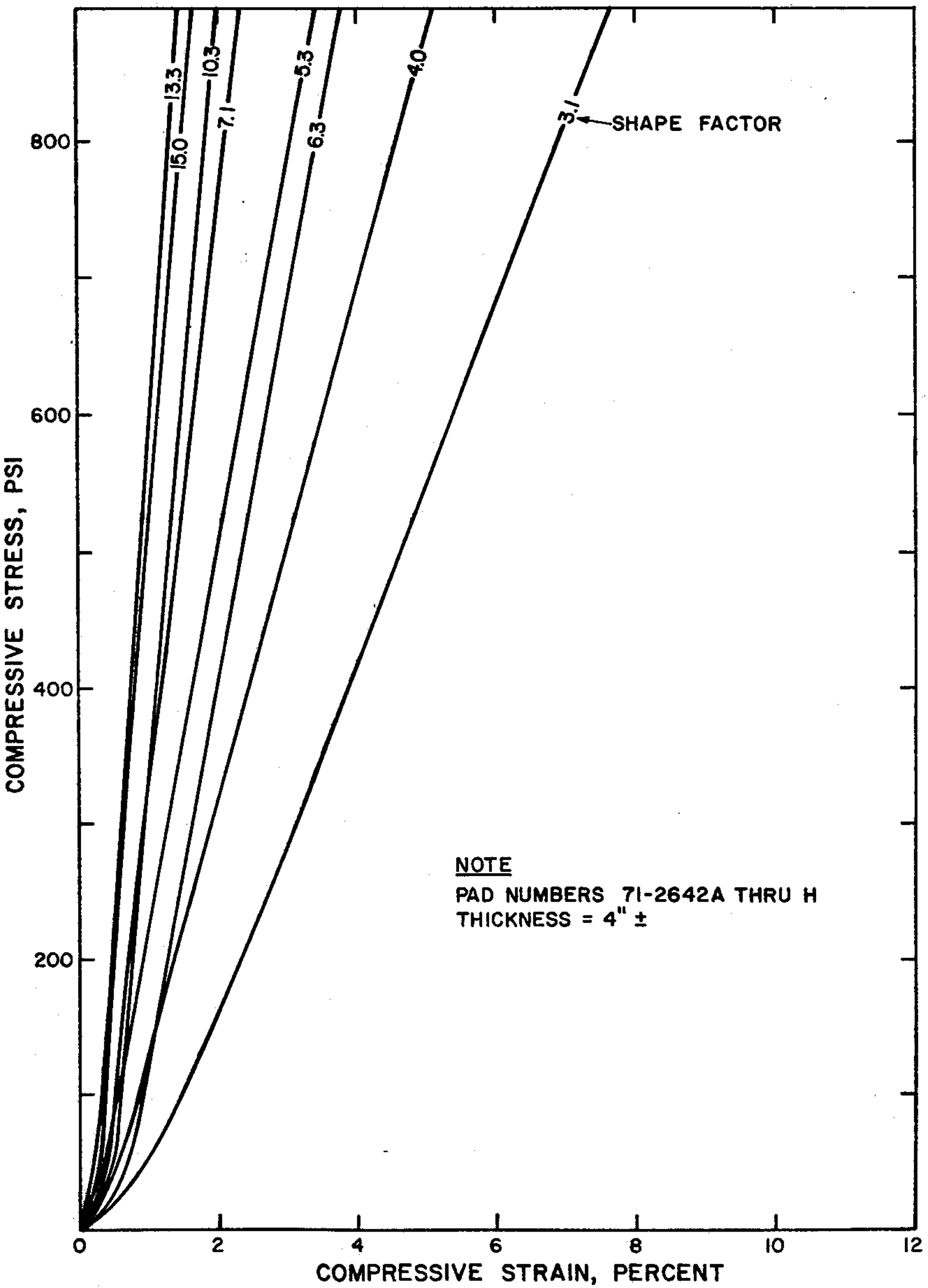



**Fig. 7 COMPRESSIVE STRESS / STRAIN DATA FOR STEEL REINFORCED PADS**

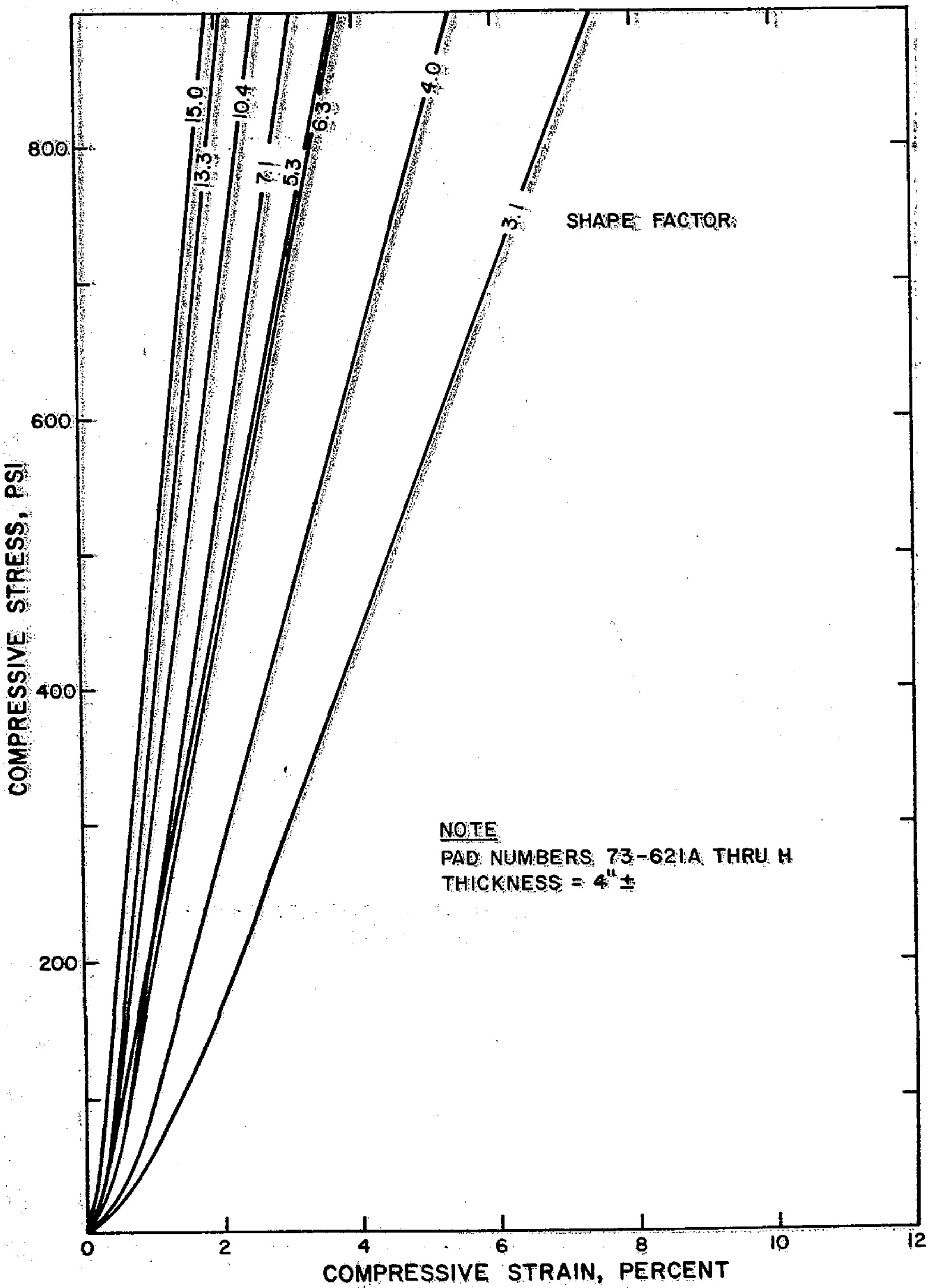



Fig. 8 COMPRESSIVE STRESS/STRAIN DATA FOR FIBERGLASS REINFORCED PADS

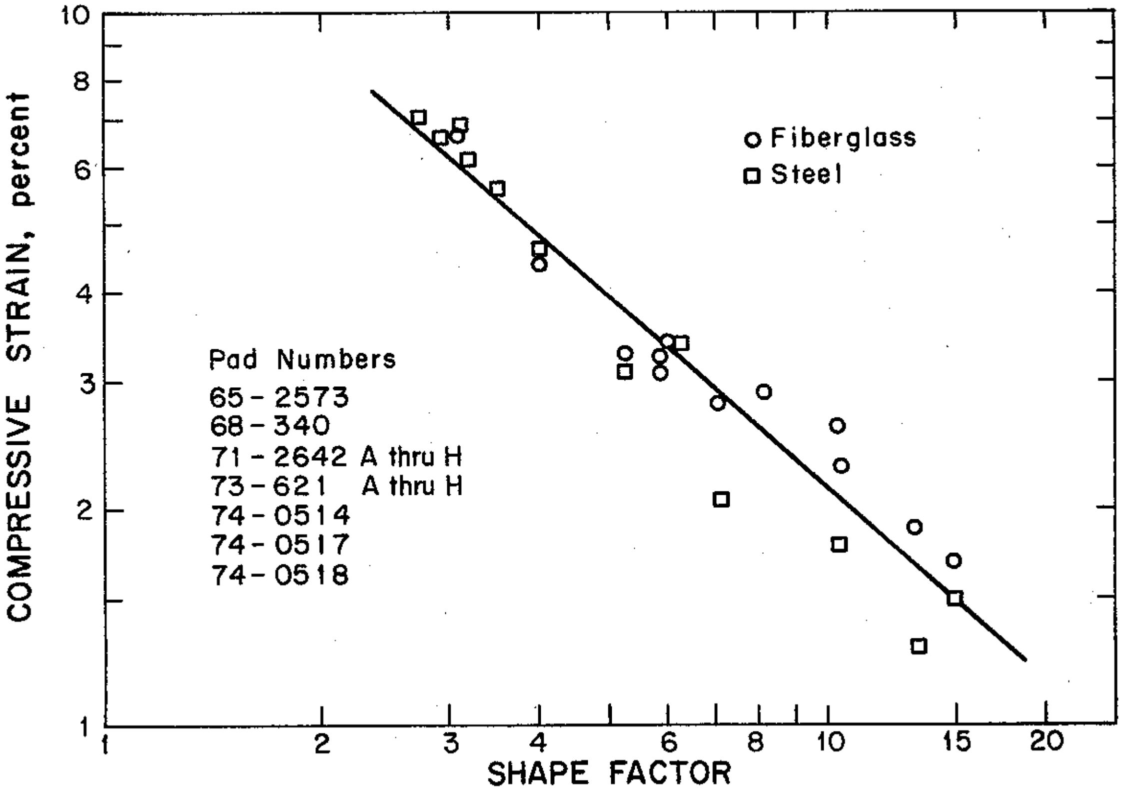



Figure 9 COMPRESSIVE STRAIN VERSUS SHAPE FACTOR AT 800 PSI COMPRESSIVE STRESS

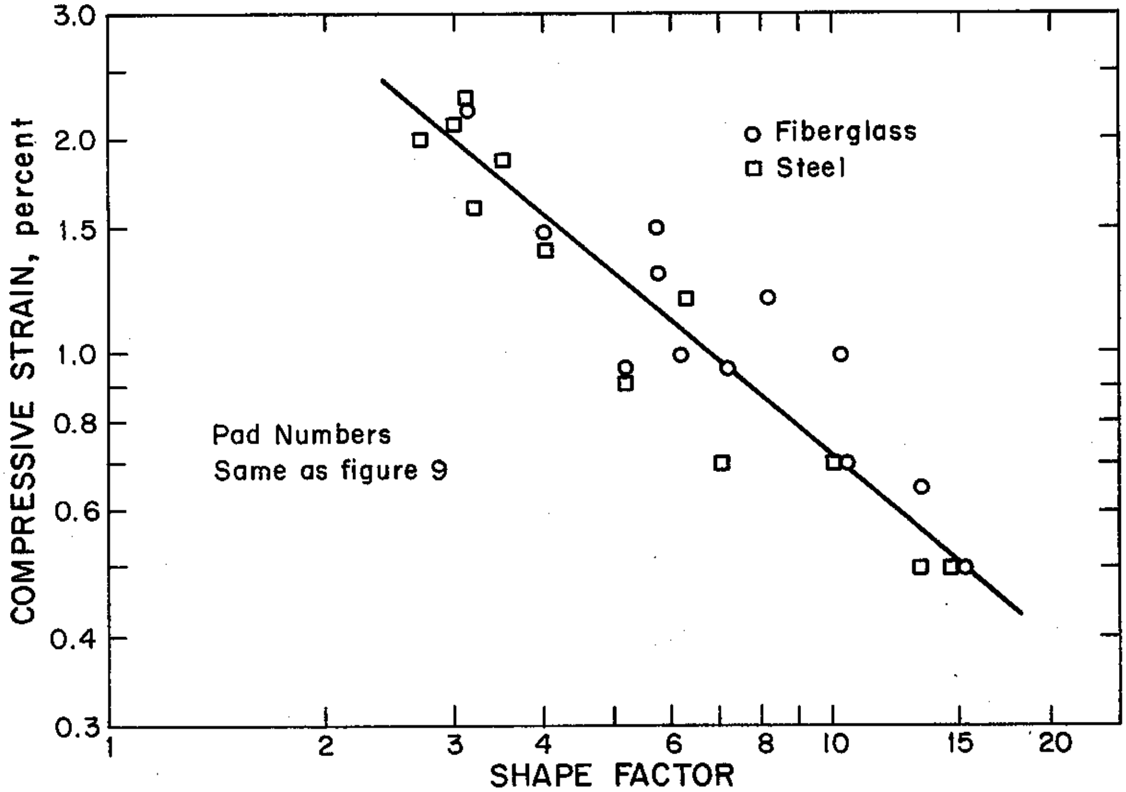



Figure 10 COMPRESSIVE STRAIN VERSUS SHAPE FACTOR AT 200 PSI COMPRESSIVE STRESS

Figures 9 and 10 also illustrate, via the data scatter, the amount of variation one might expect between the predicted compressive deflection and the actual deflection obtained. This data indicates that for most installations this variation would not be critical. For instance, if the variation from predicted strain was one percent for a 5 inch thick pad, the variation in pad deflection would be only 0.05 inch - not a substantial amount in light of normal construction tolerances.

## C. Effect of Pad Thickness on Compressive Stress/Strain Behavior

### 1. Test Procedure

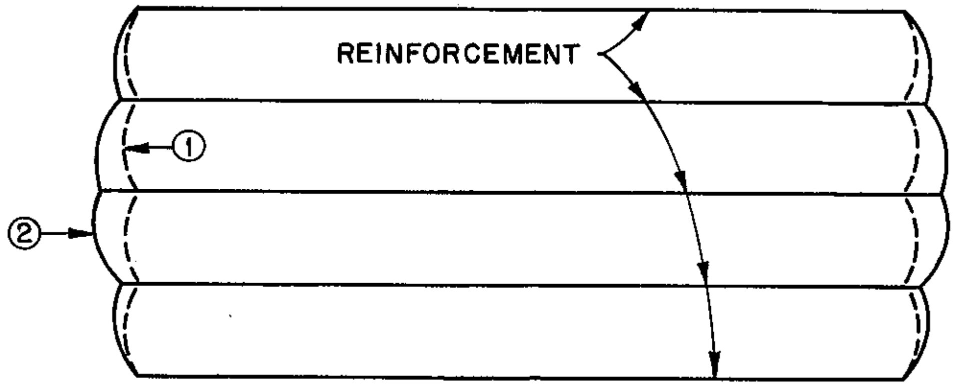
The structural system of a reinforced elastomeric bearing pad is such that as the overall pad thickness is increased, the compressive stiffness of the pad tends to decrease although the shape factor is held constant. This tendency increases as the tensile stiffness of the reinforcement decreases as illustrated in Figure 11. The more flexible the reinforcement, the more the pad bulges laterally with resultant increase in compressive deflection. This characteristic in itself is not undesirable as long as the dependency of compressive strain upon pad thickness is quantified such that compressive deflections could be accurately predicted. Laboratory testing by California and others has revealed that the compressive strain of polyester reinforced pads is significantly dependent on the overall pad thickness [3].

Early in this research project, a testing program was planned to quantify this effect of thickness on polyester reinforced pads. As it became apparent that polyester reinforced pads would no longer be used in thicknesses exceeding one inch, this testing program was abandoned, and the emphasis was shifted to assuring that the compressive strain of fiberglass or steel reinforced pads was not significantly dependent upon overall pad thickness.

Pads with varying overall thicknessess were loaded in compression as described in Section IV.B. The different thicknesses were achieved by successively stacking identical pads on top of each other. The pads were considered identical since they were cut from the same original larger pad.

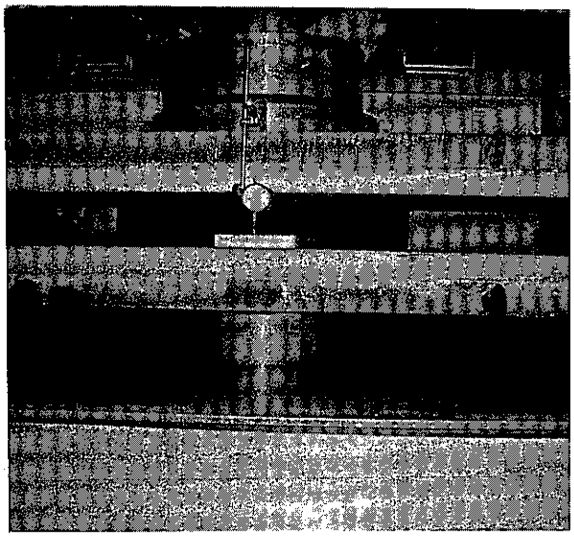
### 2. Test Results

Figure 12 illustrates the substantial effect overall pad thickness has on the compressive stress/strain behavior of polyester reinforced pads. No effort has been made to quantify this effect because it appears that such pads will not be used in thicknesses exceeding one inch.

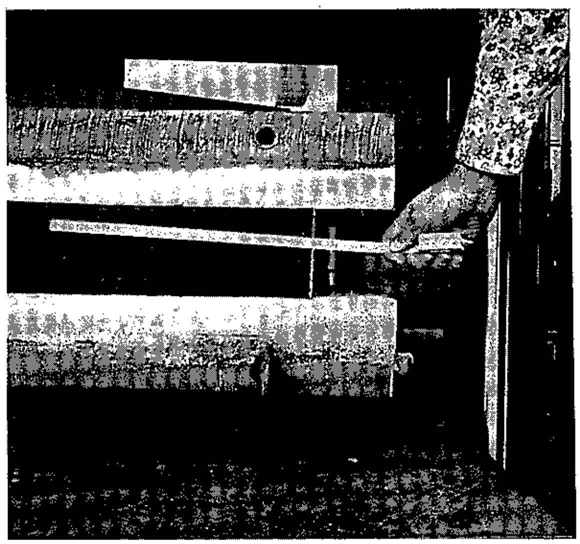



(1) STEEL OR FIBERGLASS REINFORCED PAD.

(2) POLYESTER REINFORCED PAD.



FIBERGLASS REINFORCED



POLYESTER REINFORCED

**Figure 11 COMPARISON OF PAD CONFIGURATIONS UNDER 1000 PSI COMPRESSIVE LOAD**

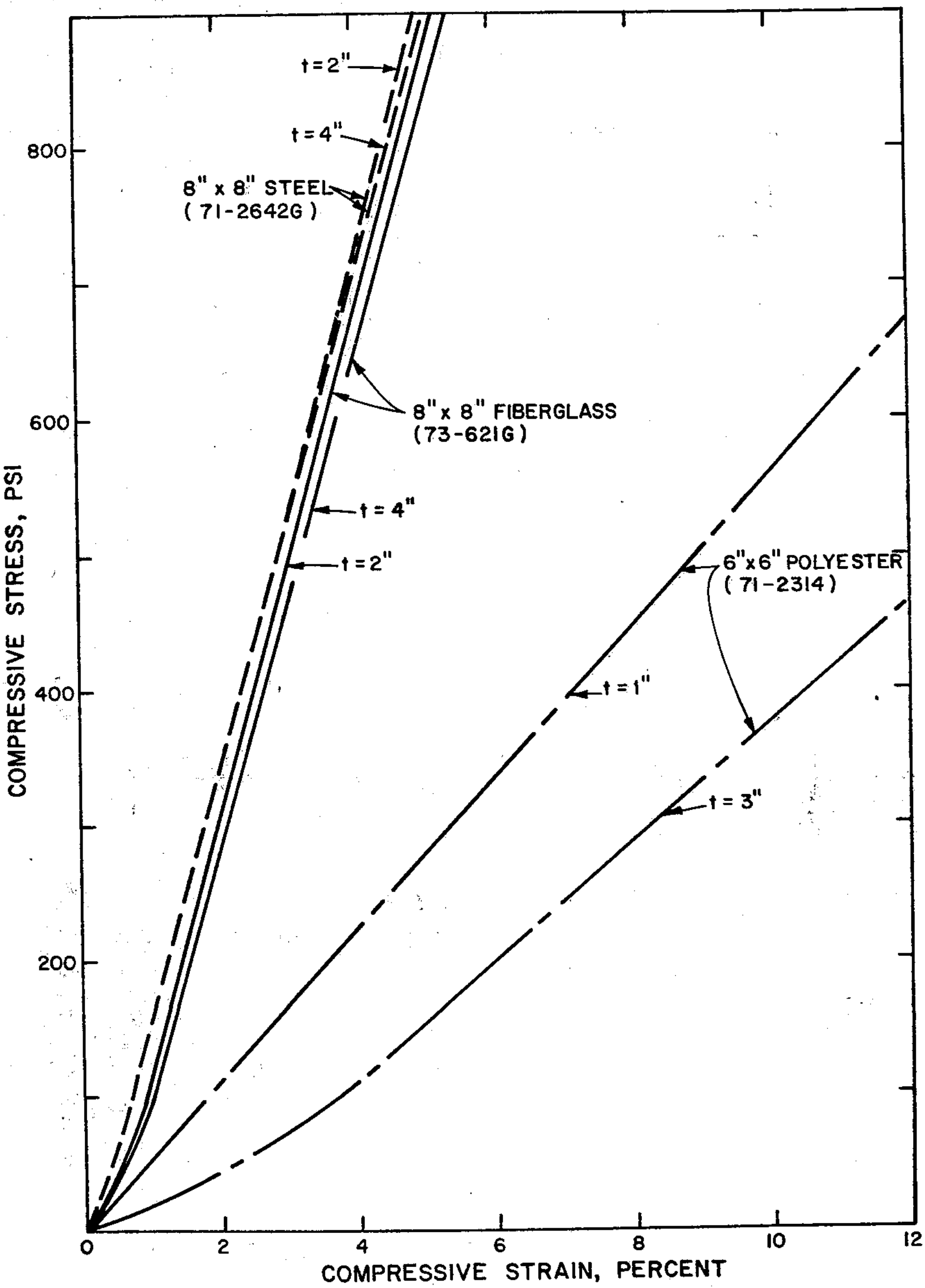



**Fig. 12 EFFECT OF OVERALL PAD THICKNESS ON COMPRESSIVE STRESS/STRAIN BEHAVIOR WITH CONSTANT SHAPE FACTOR**

Figure 12 also shows that the compressive stress/strain behavior of fiberglass or steel reinforced pads is not significantly dependent upon overall pad thickness. Therefore, the recommended compressive stress/strain curves of Figure 1 apply to all fiberglass or steel reinforced pads regardless of overall pad thickness.

## D. Compressive Creep, Static and Dynamic

### 1. Test Procedure

For a bridge bearing pad to creep excessively under sustained compressive loads would be highly undesirable because of the resulting differential elevation of the two sides of the expansion joint, i.e. - a bump in the roadway which would vary in magnitude as long as the bearing pad continued to creep. Therefore, several test pads were subjected to compressive loading conditions simulating sustained dead load and repetitive live load to assess the amount of creep to be expected.

Current CALTRANS design practice limits the nominal compressive stress on a pad to 800 psi due to dead load, live load, and impact load. For testing purposes a dead load stress of 575 to 600 psi was selected to represent typical dead load stresses in a bridge bearing pad. Test pads were subjected to these stress levels using the test apparatus described in Section IV.B. The test machine was set to automatically hold a constant load throughout the test. Compressive deflections were recorded versus time and the data reduced in accordance with the equation[3]:

$$\text{Creep} = \left(\frac{\text{deflection at time t}}{\text{initial deflection}} - 1\right) \times 100 \text{ (percent)}$$

The dead load was sustained on the test pads for periods up to several days or until it appeared that creep was progressing at a very slow rate.

Following the static creep tests, the compressive stress was cycled from the simulated dead load stress to 800 psi to simulate a live load environment. The testing machine automatically controlled the sawtooth function at a rate of 100 cycles per hour. After 200 cycles the compressive stress was returned to the dead load stress level and the pad deflection was measured to determine the amount of strain caused by the simulated live loading. The compressive stress was then held at the dead load stress level to determine whether or not the pad would tend to recover from the strain caused by the live loading. The test was terminated when the data indicated whether or not this recovery was occurring.

The fiberglass reinforced pads used for these creep tests had not been loaded prior to the tests. The polyester reinforced and steel reinforced pads had been previously loaded to 1000 psi in short term compression but had been allowed to recover from the short term tests prior to the long term creep tests.

A few pads were also subjected to static creep tests at 1000 psi to assure that current design practice possessed a factor of safety against excessive creep.

2. Test Results

Creep test results are summarized in Figure 13. This figure clearly illustrates the unsatisfactory performance of polyester reinforced pads relative to the performance of fiberglass or steel reinforced pads. The creep of polyester reinforced pads can exceed 30 percent of their initial deflection after 24 hours under dead load conditions while the corresponding creep for fiberglass and steel reinforced pads is approximately 10 percent.

Figure 13 also illustrates the relative performance of different reinforcement materials under simulated live load conditions. Although all pads experienced creep due to the 200 cycles of live load, the fiberglass reinforced and steel reinforced pads tended to recover from this dynamic creep when the load was returned to the dead load condition while the polyester reinforced pads failed to make this recovery. This indicates that over a long period of service that the deflection of polyester reinforced pads would tend to increase due to creep caused by live loads.

Figure 14 presents data from creep tests on a logarithmic scale in order to make long term projections of creep. This figure again illustrates the undesirable creep characteristics of polyester reinforced pads, and also supplies an estimate of creep after a number of years. Based on this data, creep of about 20 percent would be realized after ten years of sustained dead load on fiberglass or steel reinforced pads. This is in agreement with the DuPont ten year test data which indicates creep of 25 percent after ten years[2[. Therefore, current California design criteria which estimate creep to be 25 percent over the lifetime of a bridge appear to be reasonable.

Figure 15 illustrates the creep of fiberglass reinforced and steel reinforced pads under a static load of 1000 psi. As would be expected the creep at 1000 psi tends to be higher than that at 600 psi but it is not considered excessive. This indicates that steel or fiberglass reinforced pads designed for dead load stresses of approximately 600 psi possesses a substantial factor of safety against excessive creep.

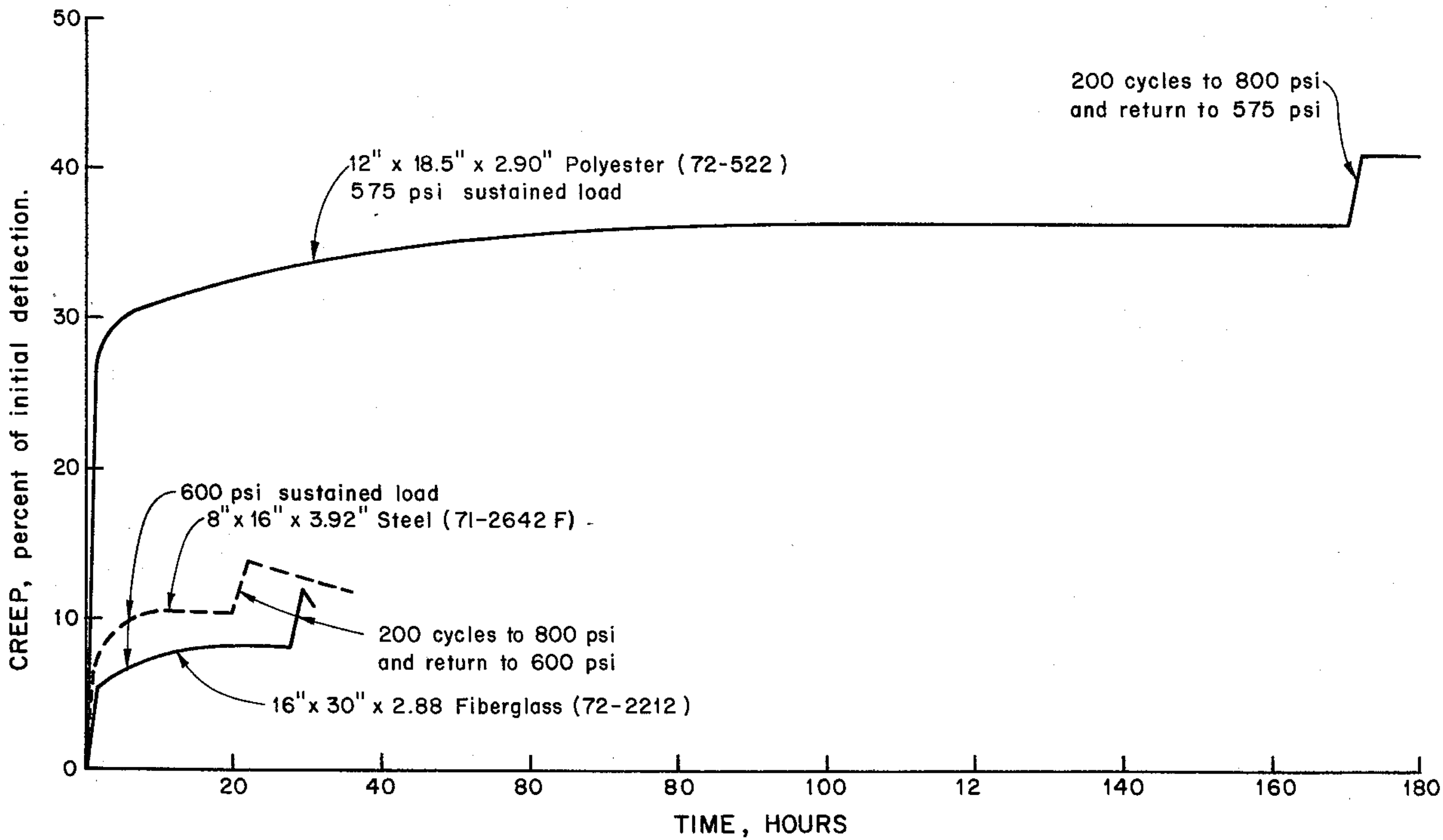



Figure 13, TYPICAL COMPRESSIVE CREEP CURVES UNDER SIMULATED DESIGN LOADS

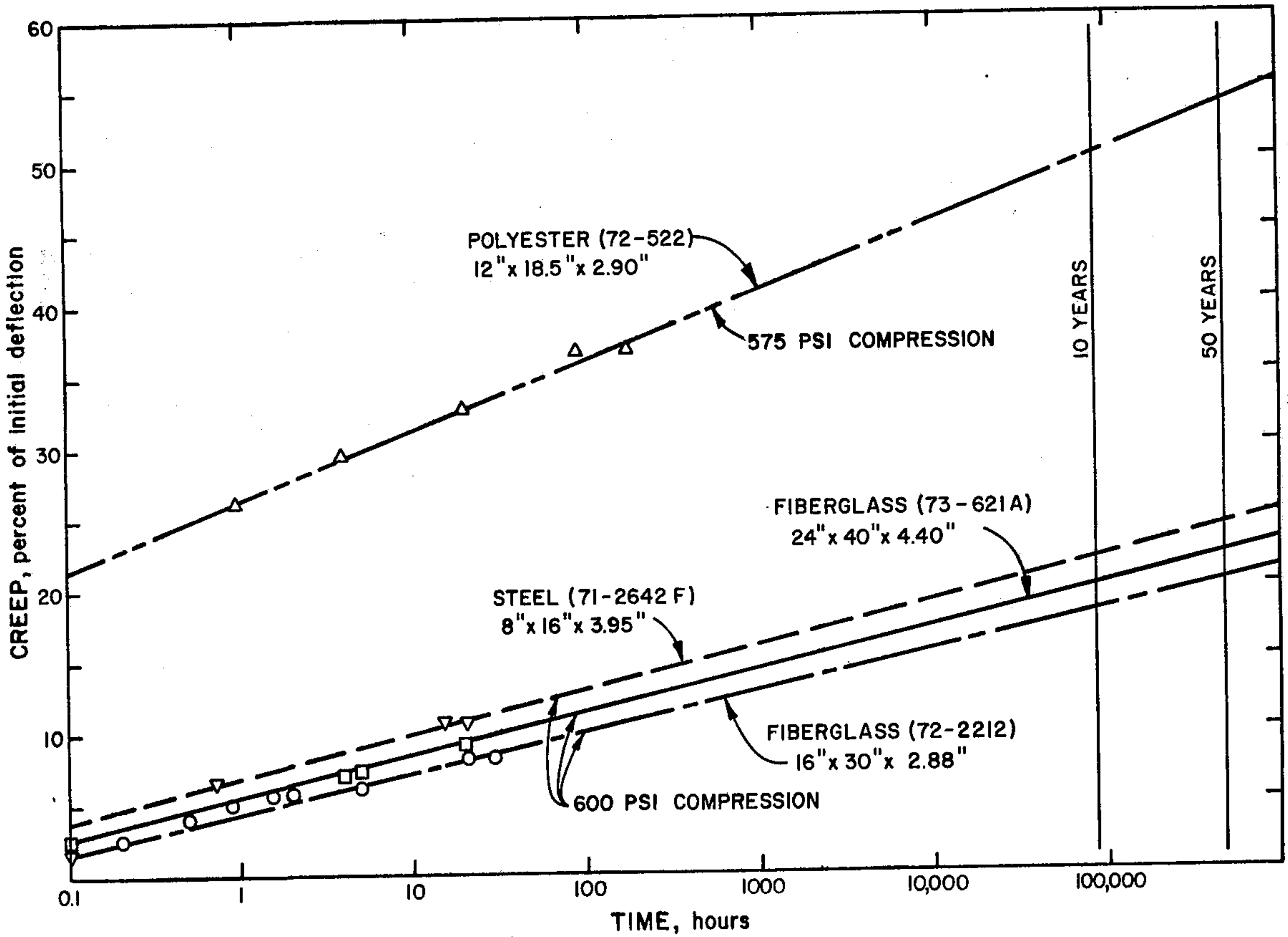



Figure 14 CREEP UNDER SIMULATED DEAD LOAD COMPRESSIVE STRESS

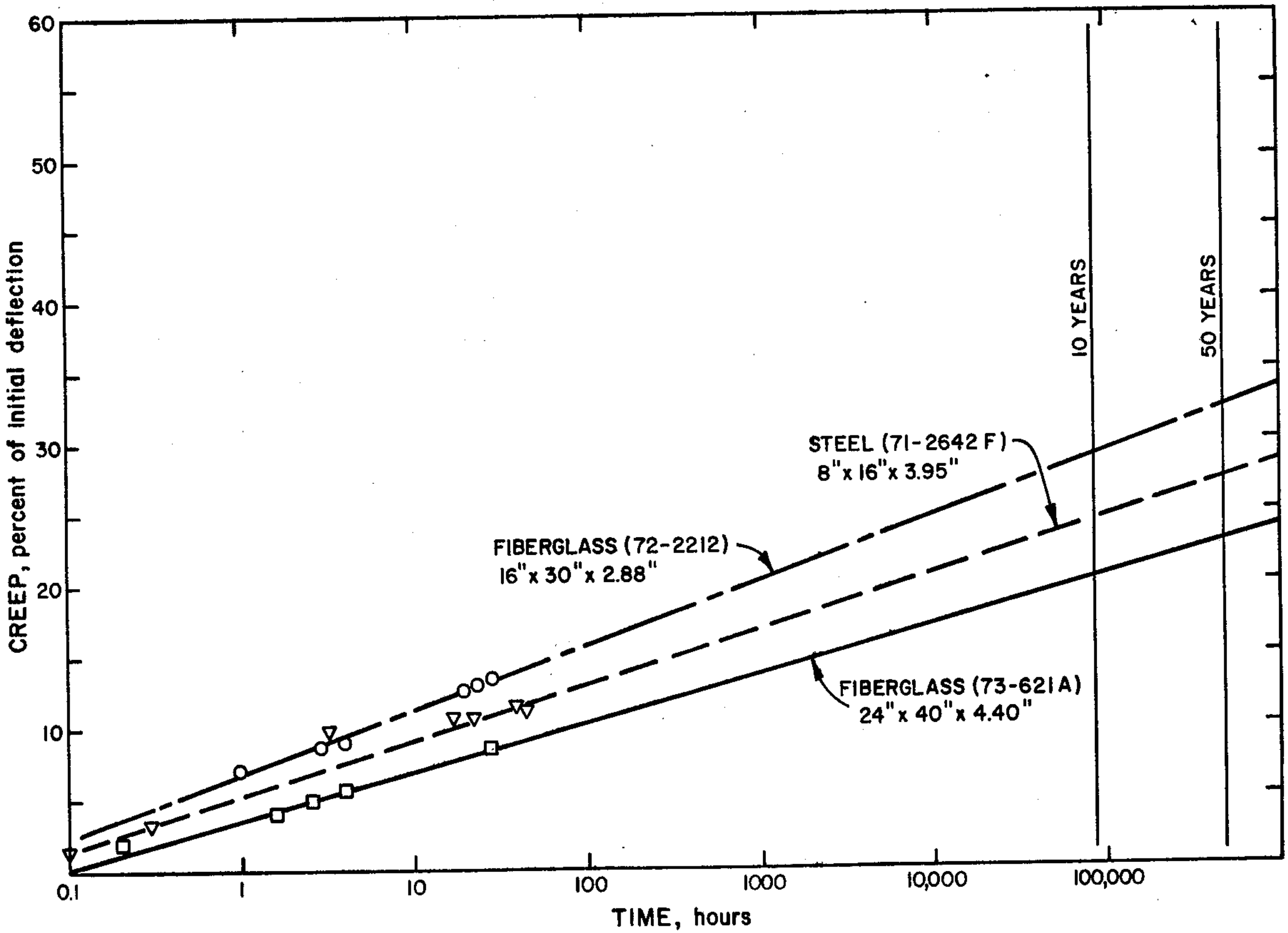



Figure 15 CREEP UNDER 1000 PSI COMPRESSIVE STRESS

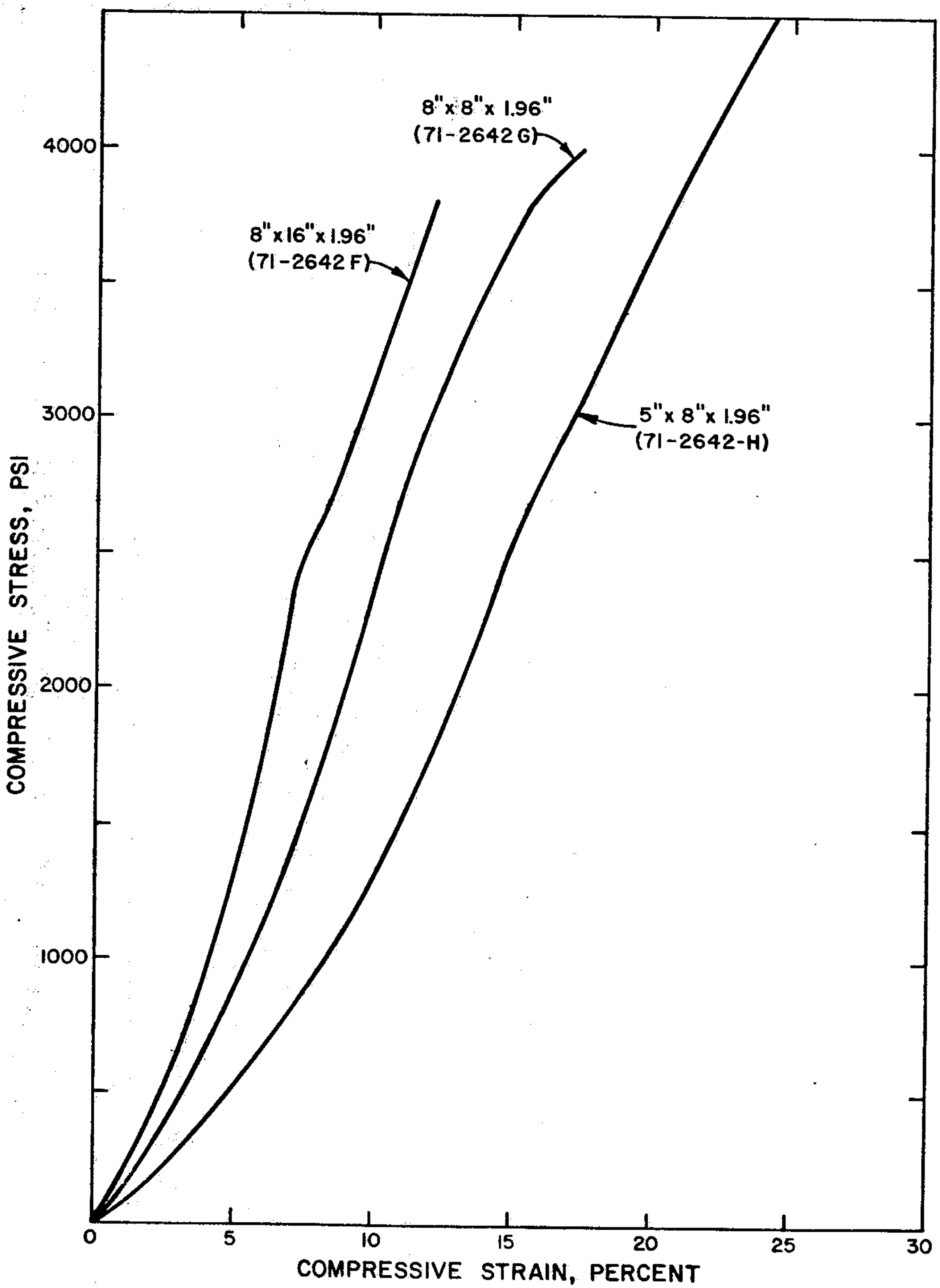



Fig.16 ULTIMATE STRENGTH TESTS OF STEEL REINFORCED PADS

## E. Ultimate Strength in Compression

### 1. Test Procedure

Current CALTRANS design practice limits the nominal compressive stress to 800 psi. In order to estimate the factor of safety against pad failure in compression, several pads were subjected to ultimate strength tests. Because of the 1,000,000 pound capacity of the testing machine, the size of the test pads were limited.

The pads were loaded and data acquired as described in Section IV.B except that the load was increased in 100 psi increments until the pad had failed or yielded.

### 2. Test Results

Figure 16 presents the stress/strain curves for steel reinforced pads. At a compressive stress level of 2400 to 2800 psi the slopes of the curves decreased indicating that the steel reinforcement was yielding. Based on the theoretical equations of Rejcha, the tensile stress in the 20 gage mild steel reinforcement is about 36,000 psi at this compressive stress level[4]. After yielding, the pads could carry much more load although their compressive stiffness was substantially diminished. Figure 17 illustrates the yielded shape of a steel reinforced pad with the maximum amount of bulging being at the center of the long side of the pad. Inspection of such pads indicated that no loss of bond between the elastomer and the steel reinforcement occurred until the compressive stress exceeded 4000 psi.

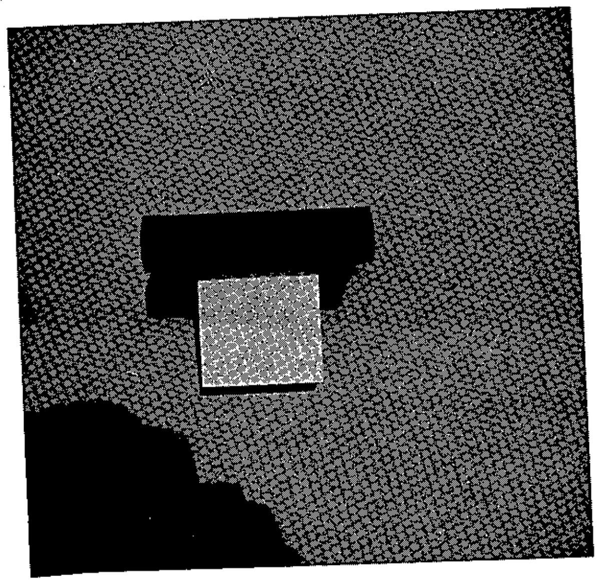


Figure 17 Steel Reinforced Pad After Carrying 4000 psi Compression

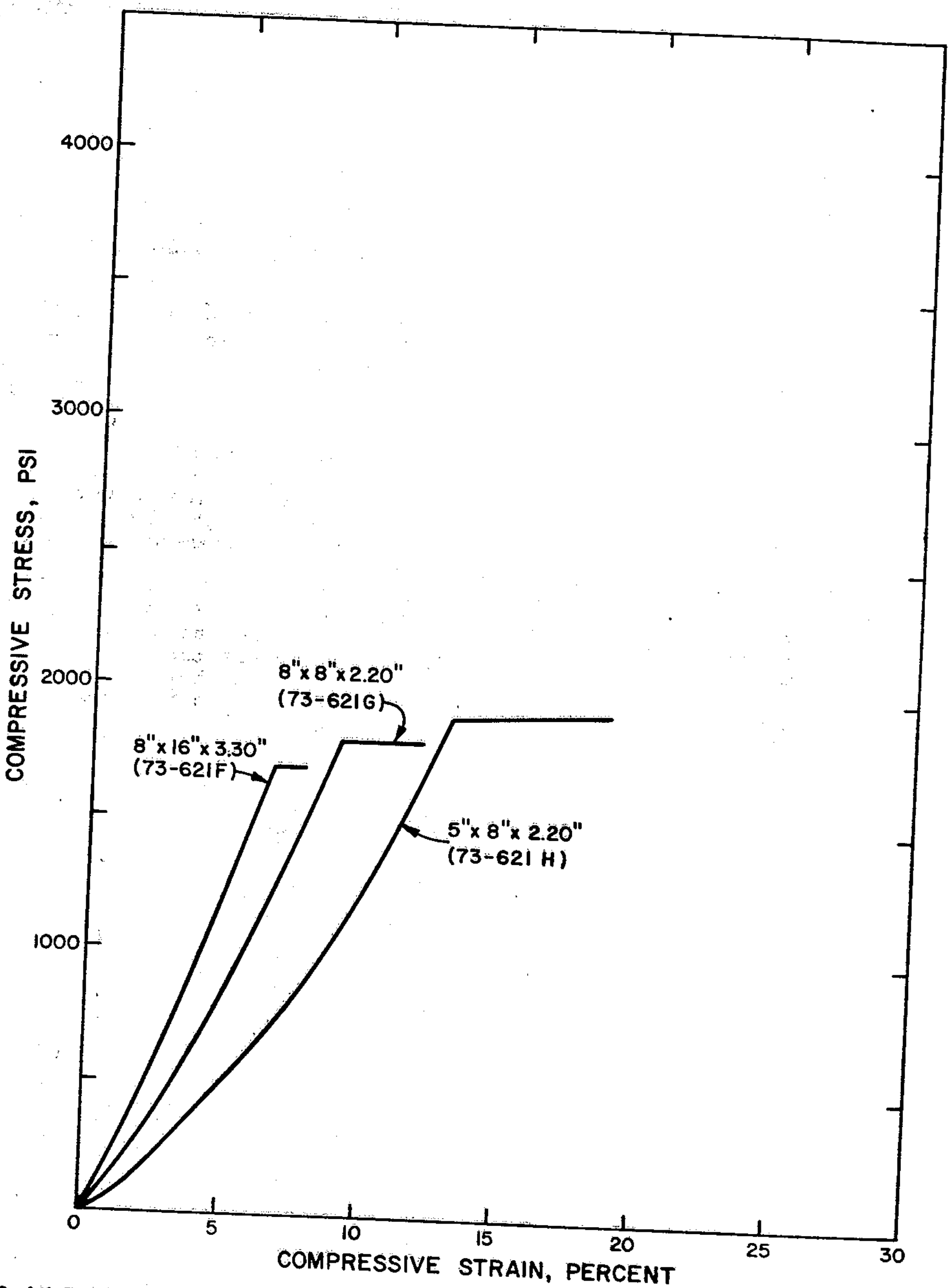



Fig.18 ULTIMATE STRENGTH TESTS OF FIBERGLASS REINFORCED PADS

Figure 18 presents the stress/strain curves for fiberglass reinforced pads. At a compressive stress level of 1700 to 1900 psi the sound of tearing fabric was heard and the pads could carry no further increase in load. According to the Rejcha equations the theoretical tensile load in each ply of the fiberglass reinforcement at this point is about 450 pounds per inch[4]. The ultimate tensile strength of each ply of fiberglass in the test pads was about 700 pounds per inch as determined by a unidirectional tensile test. Figure 19 illustrates the center layer of fiberglass following an ultimate strength test. It appears that tearing initiates at the geometric center of the pad and progresses outward toward one edge. Following this initial tear, the pad becomes, in effect, two smaller pads which attempt to carry the imposed load. These two smaller pads in turn tear resulting in the pattern shown in Figure 19. Following the ultimate strength tests, there was no appearance of loss of bond between the elastomer and the fiberglass reinforcement.

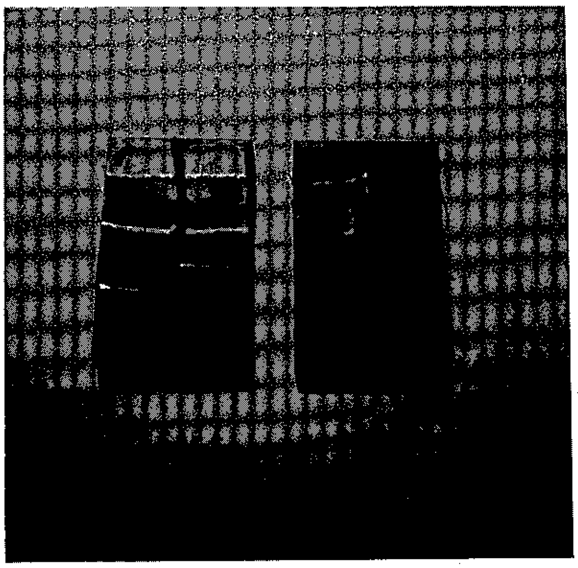


Figure 19 Fiberglass Reinforced Pad After Ultimate Strength Test

Figure 20 presents a stress/strain curve for a polyester reinforced pad. The pad behaved very much like the fiberglass reinforced pads except for the obvious difference in compressive stiffness. As with the fiberglass reinforced pads, failure occurs suddenly and is well defined at about 2000 psi compression.

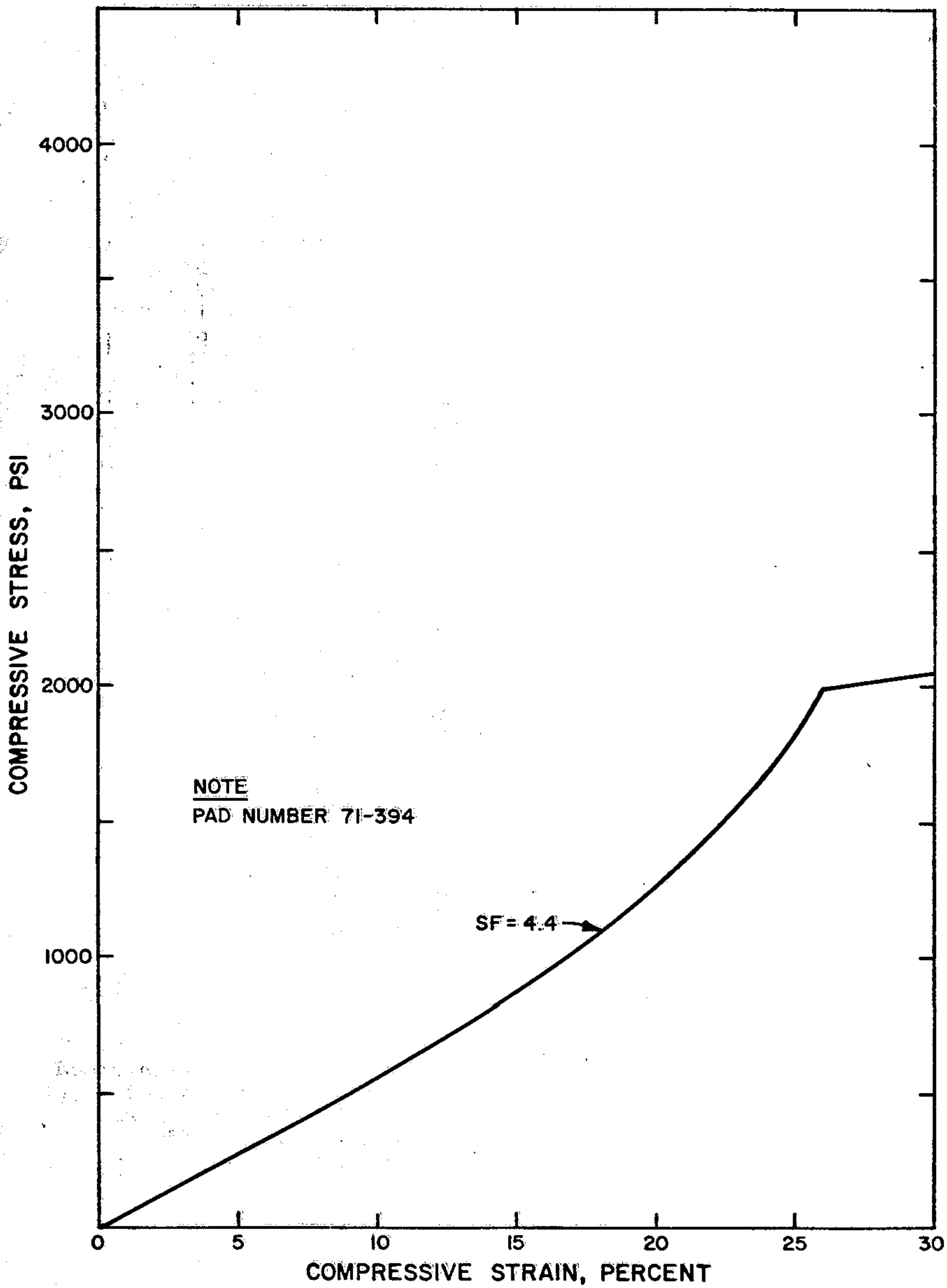



Fig.20 ULTIMATE STRENGTH TEST OF POLYESTER REINFORCED PAD

Based on these tests, one can see that fiberglass or steel reinforced pads possess a substantial factor of safety against compressive failure when designed for a compressive stress of 800 psi.

## F. Compression and Rotation

### 1. Test Procedure

Although current design criteria limit the maximum nominal compressive stress to 800 psi, local compressive stresses can be substantially higher due to the amount of rotation allowed. To simulate extreme conditions of compression combined with rotation, a series of tests were performed on fiberglass and steel reinforced pads under the conditions illustrated in Figure 21.

These conditions were achieved by moving the test pad off the centerline of the testing machine and allowing the gimbal joint of the testing machine to accommodate the rotation. The test apparatus was the same as that discussed in Section IV.B., but no deflections were measured. The amount of eccentricity was increased until a feeler gage could be placed between the loading plate and the top surface of the pad at one edge while applying a nominal compressive load of 800 psi. Under this condition, the opposite edge is undergoing the maximum compressive strain to be expected in an actual installation.

### 2. Test Results

Figure 22 shows the pad configuration in the rotated position. As expected the pad edge under maximum compressive strain bulged considerably. This area was closely inspected visually but there was no appearance of any pad failure. After releasing the load, the pads always returned to their original shape. This indicates that fiberglass and steel reinforced pads can accept the maximum rotations allowed by current design criteria without damage to the pad. CALTRANS design criteria limit the amount of rotation by requiring that bearing be maintained throughout the plan area of a pad. Under the most severe conditions allowed by these criteria, the compressive strain at one edge of the pad is zero while the compressive strain at the opposite edge is twice the strain the pad would undergo if loaded concentrically to a nominal stress of 800 psi. If the pad behaved as a linearly elastic material, the compressive stress at the loaded edge would be 1600 psi. However, because the compressive stiffness is higher near the center of the pad's plan area than at its edges, the maximum compressive stress cannot be readily determined for eccentric loading conditions[4]. To determine the distribution of compressive stresses experimentally would require extensive instrumentation and testing. Although the above tests show that the pads are capable of sustaining large rotations without failure, designers are encouraged to minimize rotational stresses by specifying the smallest pad width possible within the limits of the particular application.

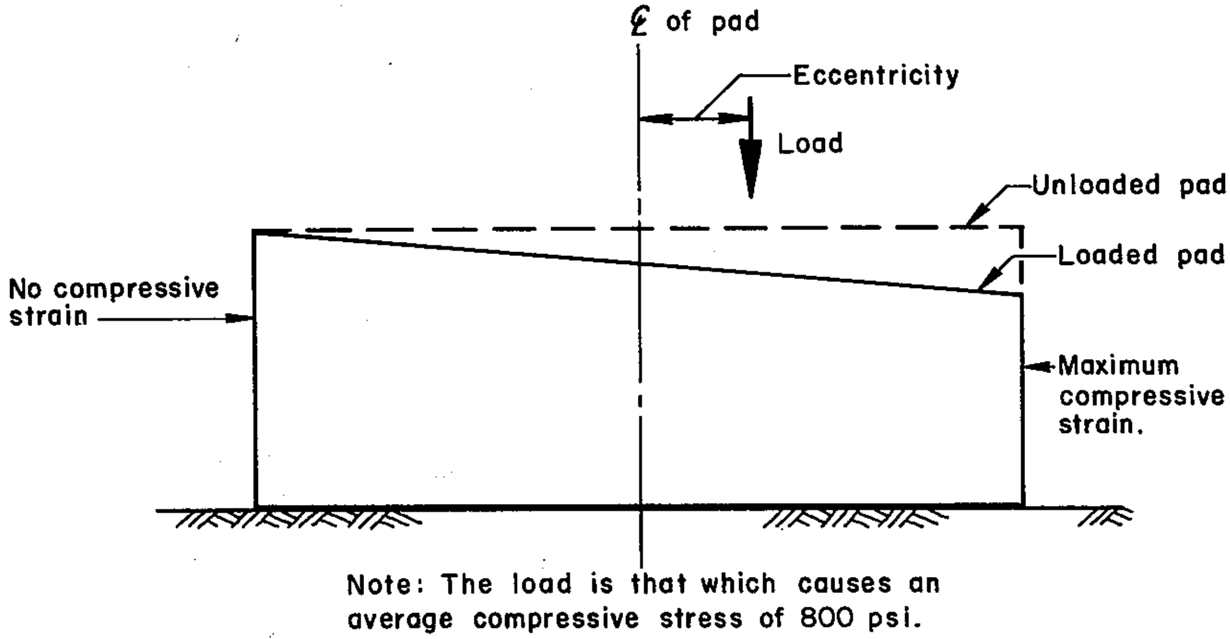
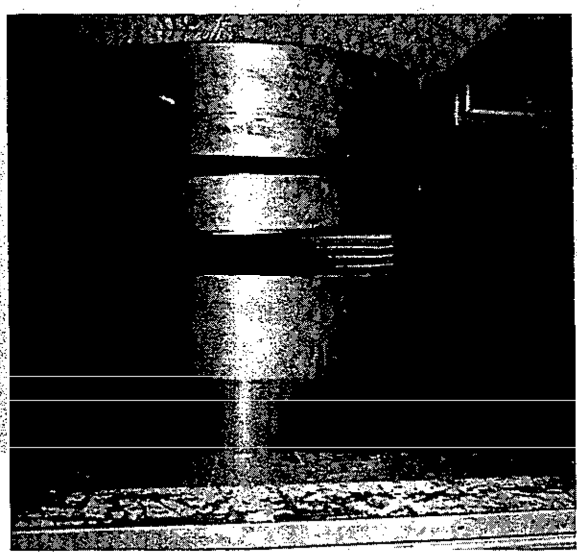
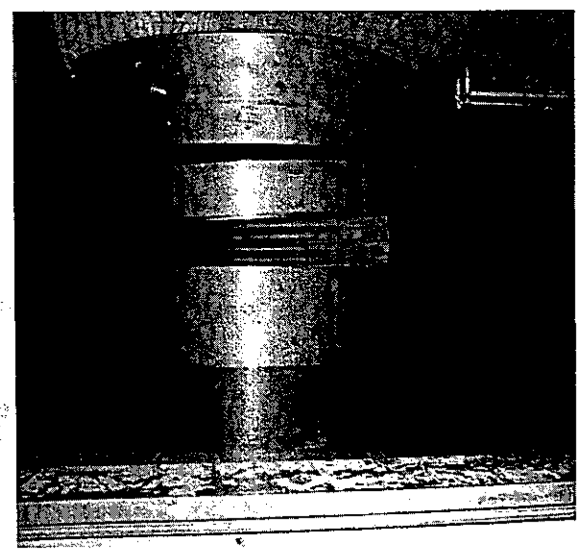



Figure 21 CONDITIONS OF ROTATION TESTS



STEEL REINFORCED



FIBERGLASS REINFORCED

Figure 22 ROTATION TESTS OF TYPICAL TEST SPECIMENS

G. Compression and Translation

1. Test Procedure

Current CALTRANS design criteria for bearing pads limit the amount of lateral translation to 1/2 the pad thickness while using a shear modulus value, G, of 135 psi to compute lateral loads. The shear modulus, G, is defined as:

$$G = \text{Shear Stress} \times \frac{\text{Pad Thickness}}{\text{Pad Translation}}$$

These same criteria are used regardless of the size or shape of the pad, skew angle (defined in Figure 23), compressive stress, or type of reinforcement. A series of combined compression and translation tests were performed to determine whether or not variations in these parameters had any substantial effect on the shear modulus, vertical deflection, or overall pad behavior. Translation tests were also performed on pads which were stacked on top each other to determine if such pads could be translated without slippage between the pads.

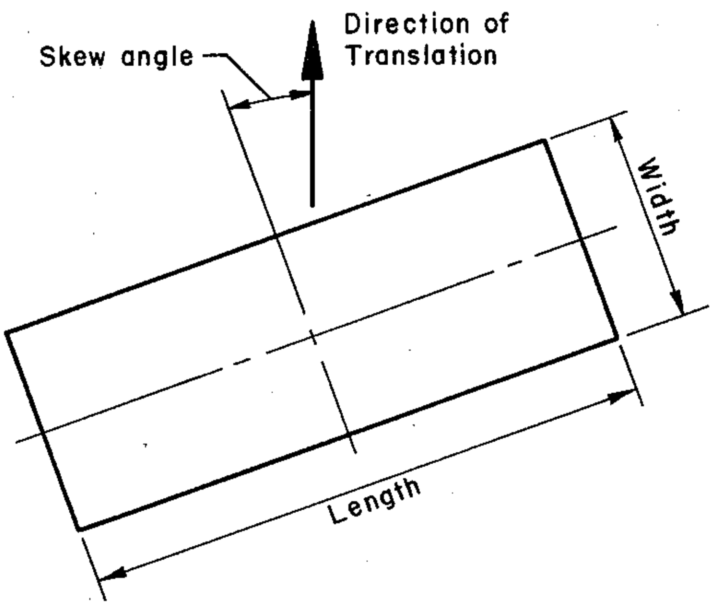



Figure 23 Definition of Skew Angle

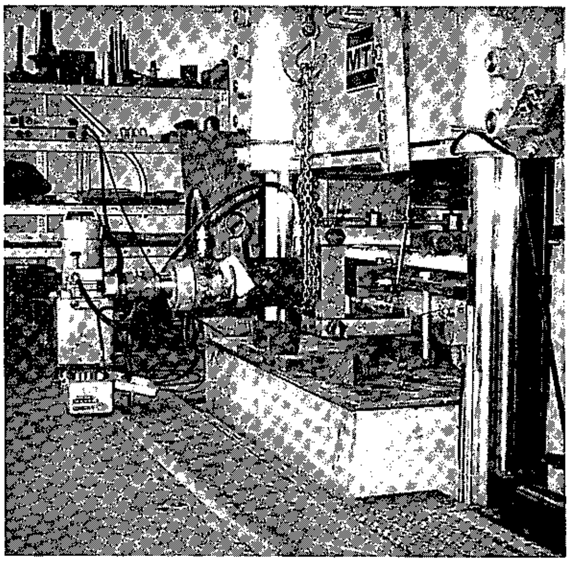
The test apparatus used for the combined compression and translation tests is illustrated in Figure 24. The one-inch thick steel plate was sandwiched between two identical test specimens and a compressive stress of 400, 600, or 800 psi was applied via the concrete and steel plates. The testing machine was set such that the compressive load remained constant throughout the translation test. Horizontal loads were applied by a 120,000 pound capacity hydraulic jack through a rather complex apparatus which is best described by the photographs presented in Figure 24. In order to keep the two concrete and steel plates parallel throughout the translation tests, braces were placed between these plates and the testing machine after the compressive load had been applied. The horizontal loads were measured by a strain gage load cell mounted on the hydraulic jack and the horizontal deflections were measured by two dial gages mounted as shown in Figure 24. Vertical load and deflection were measured by a strain gage load cell and a linear variable differential transformer within the testing machine.

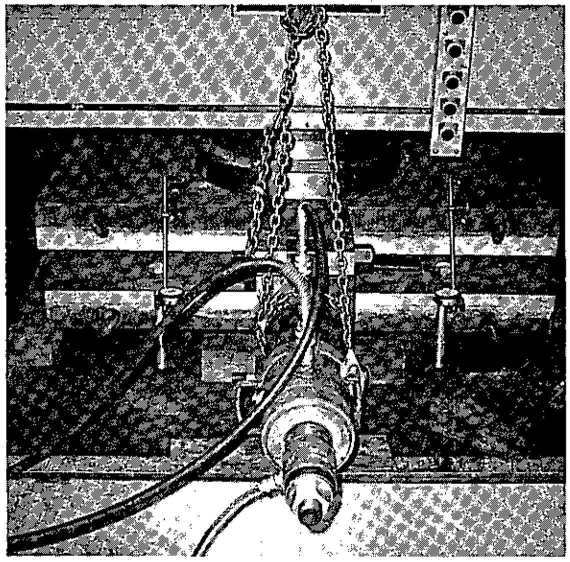
After applying the compressive load, translation was applied in increments of ten percent of pad thickness. At each increment the vertical load and horizontal load and deflection were measured as quickly as possible - within 30 seconds of obtaining the desired translation. The maximum translation for most of the tests was 100 percent of the pad thickness.

Because the shear modulus is highly dependent upon the hardness of the neoprene, the pads used for these tests possessed almost identical hardness. The shore durometer hardness of the steel reinforced pads was 53 while that of the fiberglass reinforced pads was 54.

2. Test Results

One of the obvious visual differences between steel and fabric reinforced pads when translated laterally is illustrated in Figure 25. The fabric reinforced pads tend to curl at their edges and actually separate from the loading plates at translations between 25 and 50 percent of pad thickness. Field service of fabric reinforced pads has not shown this phenomenon to be detrimental. Because of the bending stiffness of the steel sheet, the steel reinforced pads do not curl at their edges until the translation exceeds the design maximum of one-half the pad thickness. Such behavior might be detrimental under cyclic conditions where the steel would be bent back and forth beyond its yield point as shown in Figure 26.





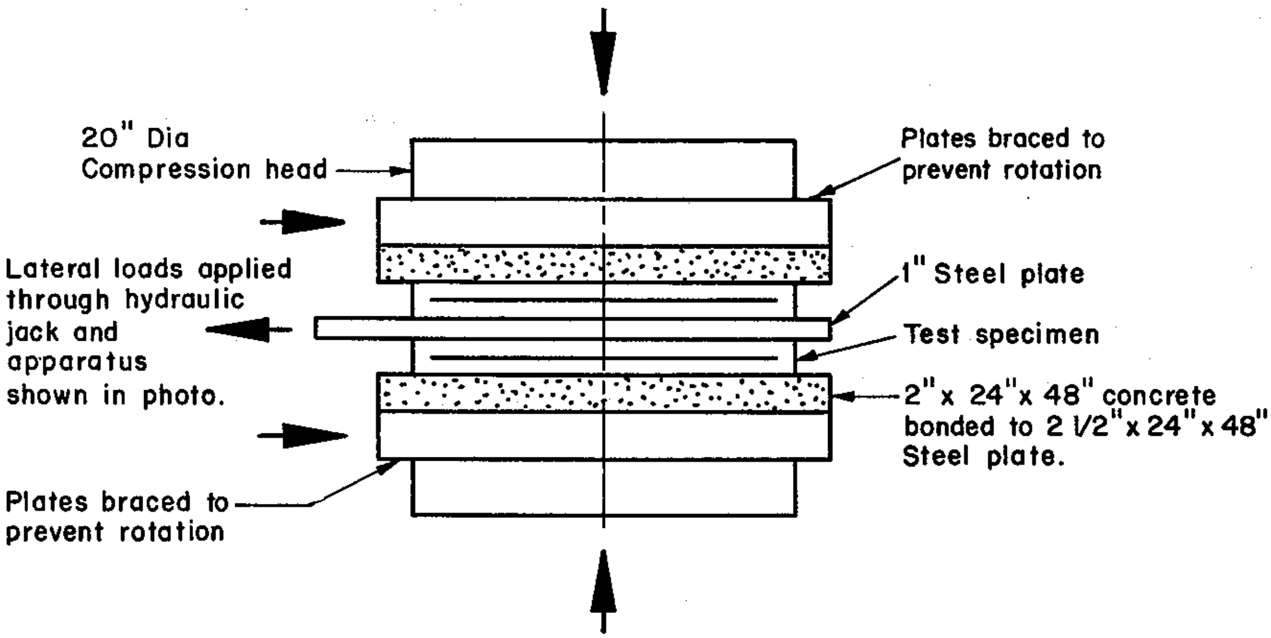
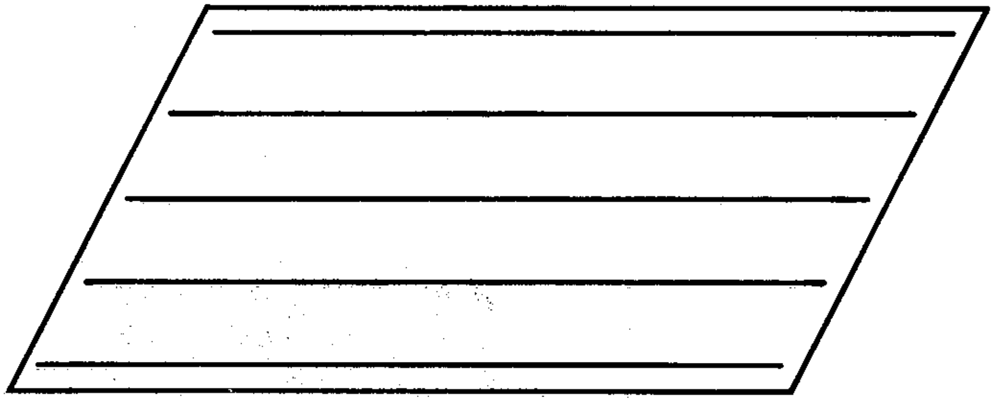
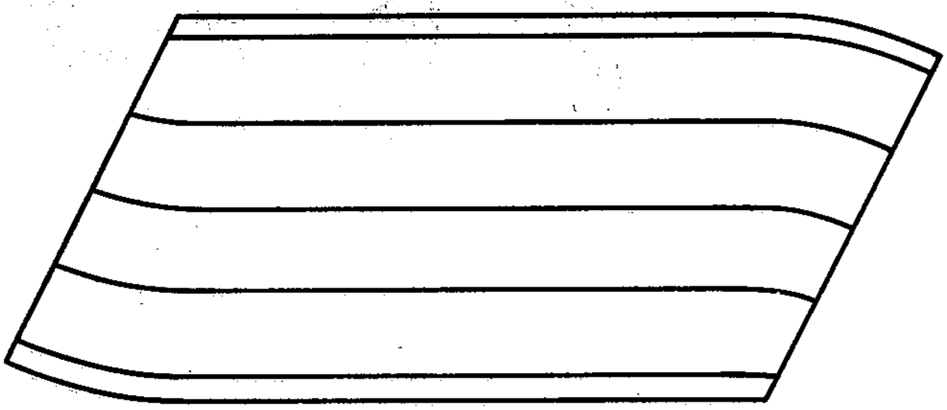


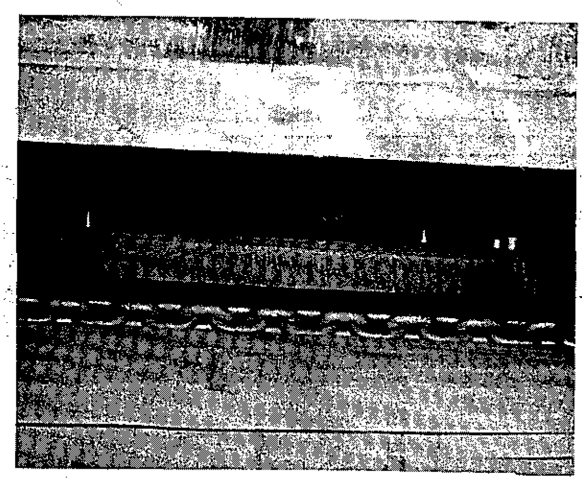

Figure 24 TYPICAL TRANSLATION TEST APPARATUS



STEEL REINFORCED



FIBERGLASS OR POLYESTER REINFORCED



FIBERGLASS REINFORCED

Figure 25 COMPARISON OF PAD CONFIGURATIONS WHEN TRANSLATED 50 PERCENT OF THICKNESS

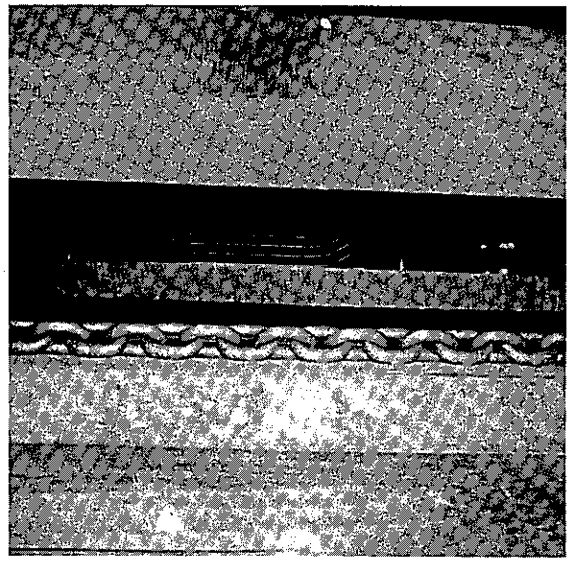


Figure 26 Steel Reinforced Pad When Translated 100 Percent of Thickness

Figure 27 compares the shear stress/strain behavior of steel reinforced pads versus fiberglass reinforced pads, and also illustrates typical data points obtained in the translation tests. It can be seen that there is no significant difference between the shear moduli of steel or fiberglass reinforced pads. Figures 28 and 29 show that this is true regardless of size or shape of the pad, skew angle, or compressive stress.

Figure 28 illustrates the effect of varying the compressive stress on the shear modulus. The shear modulus values presented represent the shear stress required to translate the pad 100 percent of its thickness. This figure shows that the shear modulus is not significantly dependent on the magnitude of compressive stress. Visual observation of the pads during these tests revealed no difference in physical behavior due to differences in compressive stress.

Figure 29 illustrates the effect of varying the skew angle on the shear modulus. This figure shows that the skew angle does not significantly affect the shear modulus. As expected, the corners of the pads tend to curl more as the skew angle is increased to 45 degrees, but this curling does not damage the pad. This curling is illustrated in Figure 30.

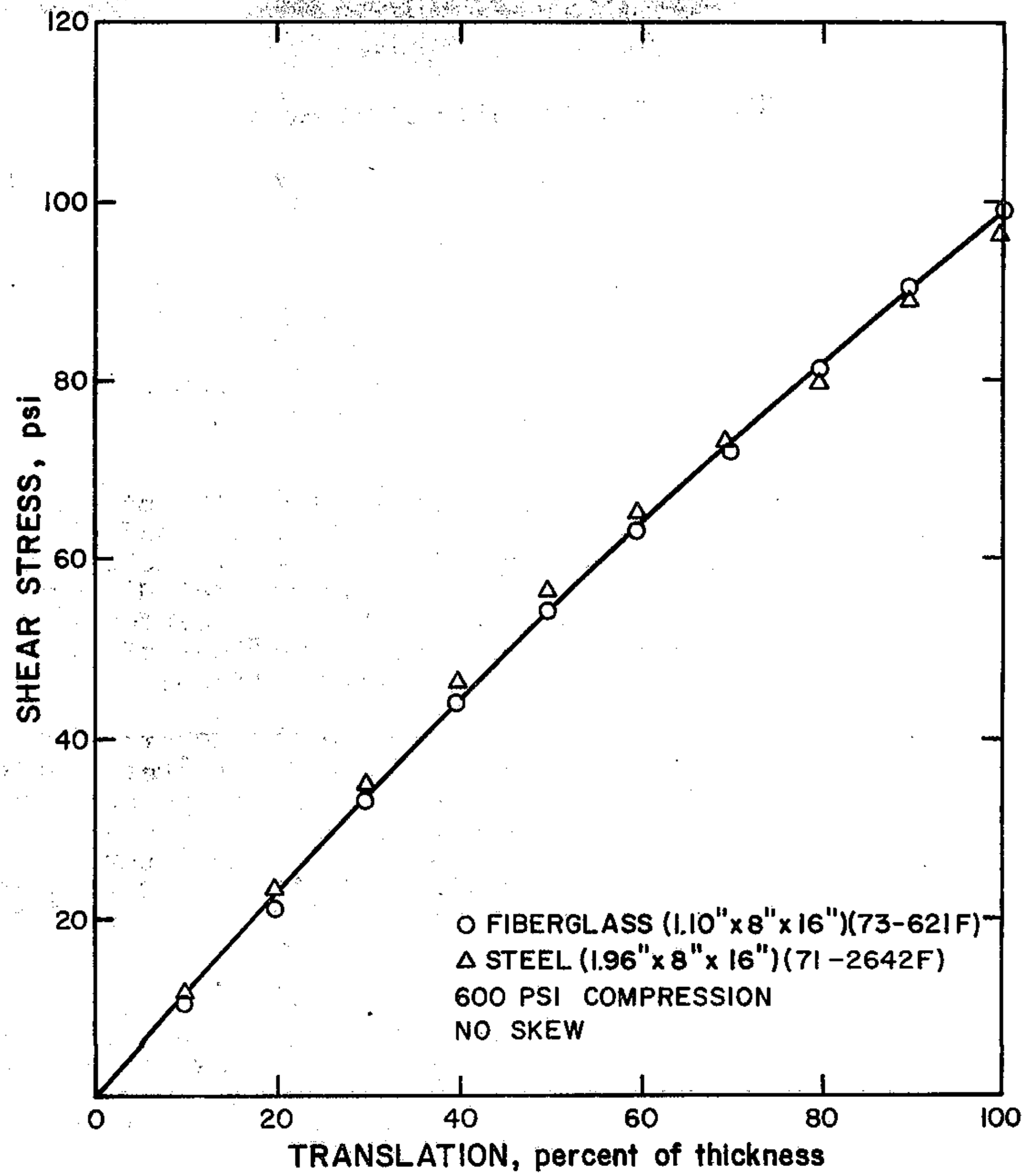



Figure 27 SHEAR STRESS VERSUS TRANSLATION FOR STEEL OR FIBERGLASS REINFORCED PADS

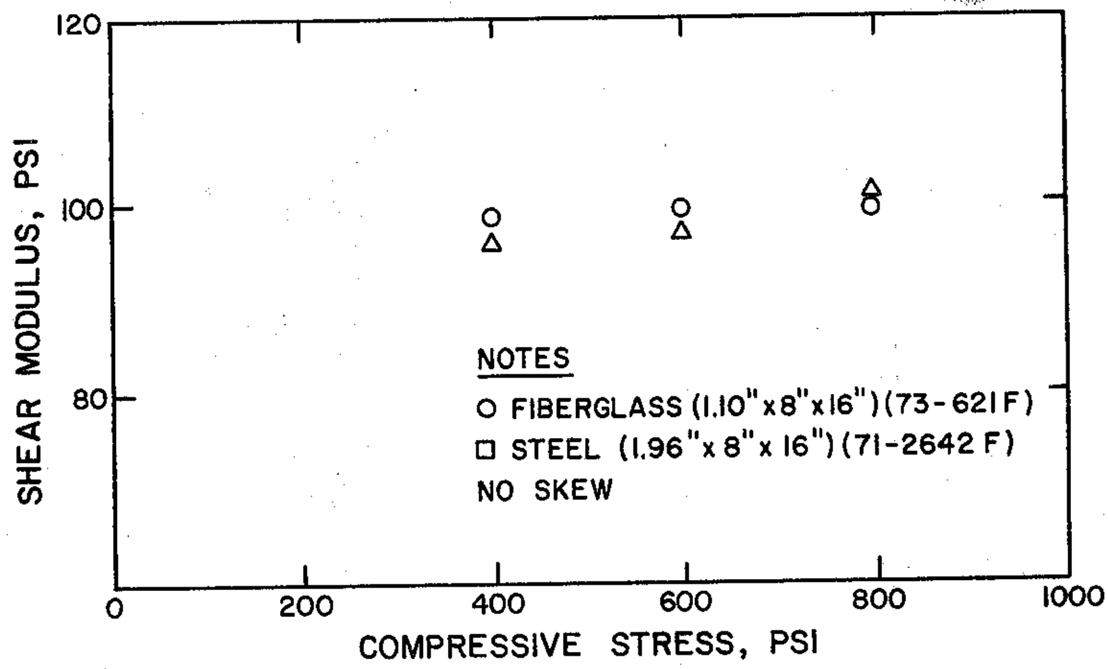



Figure 28 SHEAR MODULUS VERSUS COMPRESSIVE STRESS

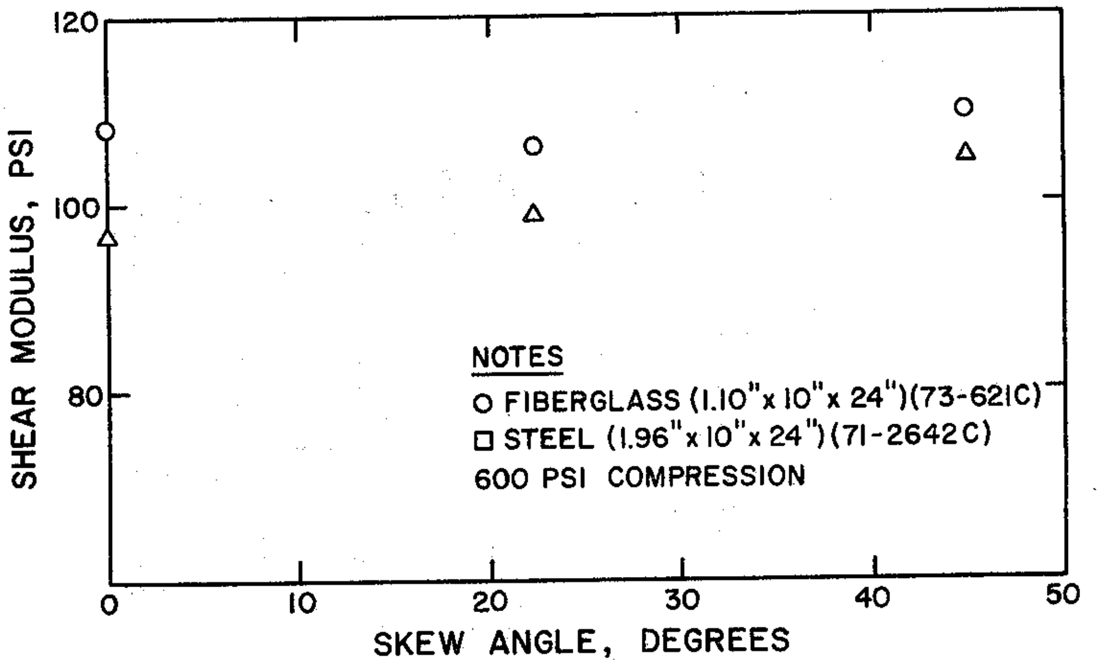
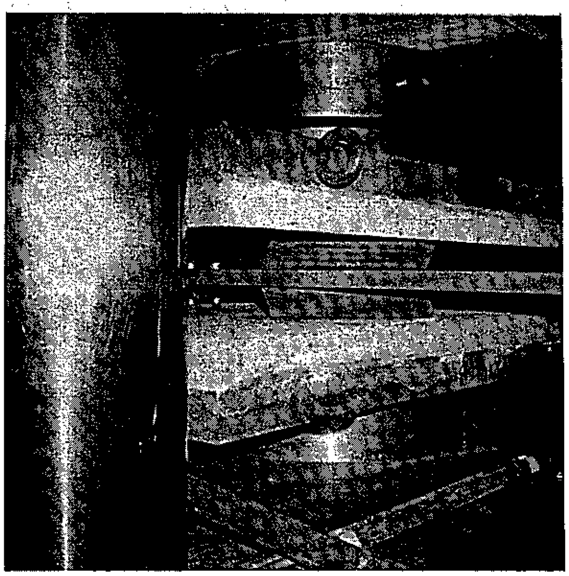
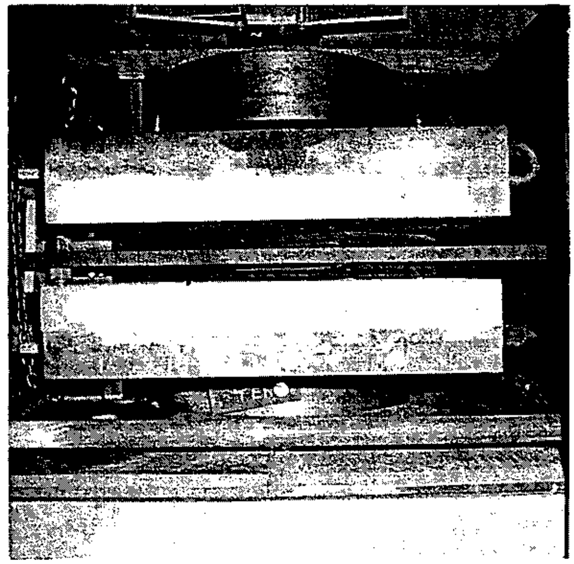



Figure 29 SHEAR MODULUS VERSUS SKEW ANGLE



Steel Reinforced



Fiberglass Reinforced

Figure 30, TRANSLATION OF 50 PERCENT OF THICKNESS AT 45° SKEW ANGLE

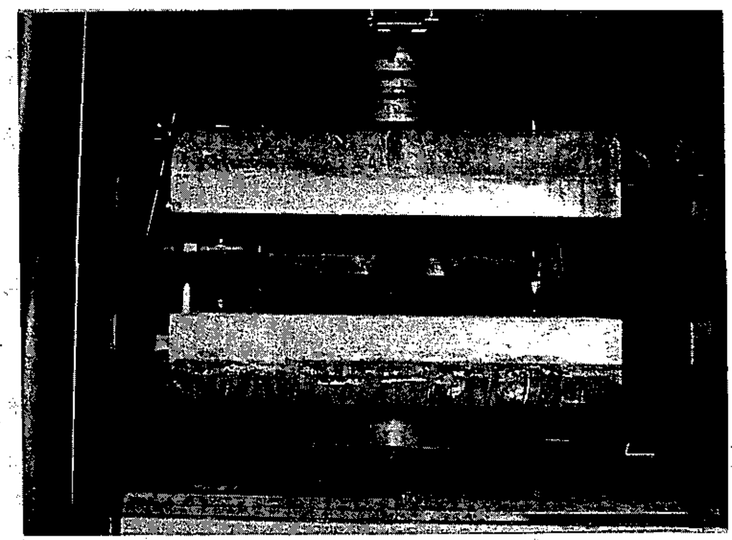


Figure 31, SLIPPAGE OF STACKED PADS DURING TRANSLATION TEST

In all the translation tests described above, the highest value of shear modulus obtained was 109 psi while the lowest was 95 psi. This indicates that the shear modulus of 135 psi used to predict lateral loads is adequate regardless of size or shape of the pad, skew angle, compressive stress, or type of reinforcement.

In all the translation tests, the vertical deflection was monitored to determine whether the translation would result in any significant vertical deflection. The vertical deflections measured at translations of 50 percent of pad thickness were small enough to be considered insignificant. For example, the largest compressive strain realized was 0.31 percent for an 8" x 16" steel reinforced pad. For a four-inch thick pad, this would amount to an 0.01 inch deflection - not enough to be concerned about in normal bridge construction.

One other parameter was investigated during the translation tests - that of stacking individual pads on top each other. Figure 31 illustrates the results of such a test. At a translation of about 25 percent of the pad thickness, the pads began to slip at their interface. Despite a compressive stress of 400 psi, the friction between the pads was not high enough to prevent slippage. This indicates that pads which are stacked to form a thicker pad must be bonded together to assure that the pad remain intact throughout its service life.

## V. REFERENCES

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2. "Design of Neoprene Bridge Bearing Pads", E. I. duPont de Nemours and Company (Inc.), April, 1959.

3. Minor, J. C., Egen, R. A., "Elastomeric Bearing Research", National Cooperative Highway Research Program Report 109, Battelle Memorial Institute, 1970.

4. Rejcha, C., "Design of Elastomer Bearings", Prestressed Concrete Institute Journal, October, 1964.

# VI. APPENDIX

## A. List of Test Specimens

The data presented in this report is from tests conducted on the test specimens listed below. These specimens are considered representative of all specimens tested.

| Pad Numbers | Reinforcement | Shape Factor | Dimensions (inches) | Durometer |
|---|---|---|---|---|
| 65-2573 | Steel | 3.2 | 1 ea 4.8x10.0x2.50* | 58 |
| 68- 340 | Steel | 3.5 | 1 ea 6.0x 8.5x2.91* | 58 |
| 71-2642A | Steel | 15.0 | 2 ea 24.0x40.0x1.96* | 53 |
| 71-2642B | Steel | 13.3 | 24.0x30.0 | 53 |
| 71-2642C | Steel | 7.1 | 24.0x10.0 | 53 |
| 71-2642D | Steel | 6.3 | 8.0x30.0 | 53 |
| 71-2642E | Steel | 10.4 | 16.0x30.0 | 53 |
| 71-2642F | Steel | 5.3 | 8.0x16.0 | 53 |
| 71-2642G | Steel | 4.0 | 8.0x 8.0 | 53 |
| 71-2642H | Steel | 3.1 | 8.0x 5.0 | 53 |
| 71- 394 | Polyester | 4.4 | 1 ea 8.0x10.0x4.51* | 48 |
| 71-2314 | Polyester | 3.0 | 6 ea 6.0x 5.9x0.54* | 55 |
| 71-2714A | Polyester | 15.0 | 2 ea 24.0x40.0x2.00* | 54 |
| 71-2714D | Polyester | 6.3 | 8.0x30.0 | 54 |
| 72- 522 | Polyester | 7.3 | 1 ea 12.0x18.5x2.90* | 55 |
| 72-2212 | Fiberglass | 10.4 | 4 ea 16.0x30.0x0.96* | 48 |
| 73- 621A | Fiberglass | 15.0 | 4 ea 24.0x40.0x1.10* | 54 |
| 73- 621B | Fiberglass | 13.3 | 24.0x30.0 | 54 |
| 73- 621C | Fiberglass | 7.1 | 24.0x10.0 | 54 |
| 73- 621D | Fiberglass | 6.3 | 8.0x30.0 | 54 |
| 73- 621E | Fiberglass | 10.4 | 16.0x30.0 | 54 |
| 73- 621F | Fiberglass | 5.3 | 8.0x16.0 | 54 |
| 73- 621G | Fiberglass | 4.0 | 8.0x 8.0 | 54 |
| 73- 621H | Fiberglass | 3.1 | 8.0x 5.0 | 54 |
| 74-0514 | Fiberglass | 5.8 | 1 ea 10.0x14.0x3.00* | 53 |
| 74-0517 | Fiberglass | 8.2 | 1 ea 12.0x26.0x3.00* | 53 |
| 74-0518 | Fiberglass | 5.8 | 1 ea 10.0x14.0x2.00* | 53 |

*Original pads tested. Other pads were cut from these original pads.

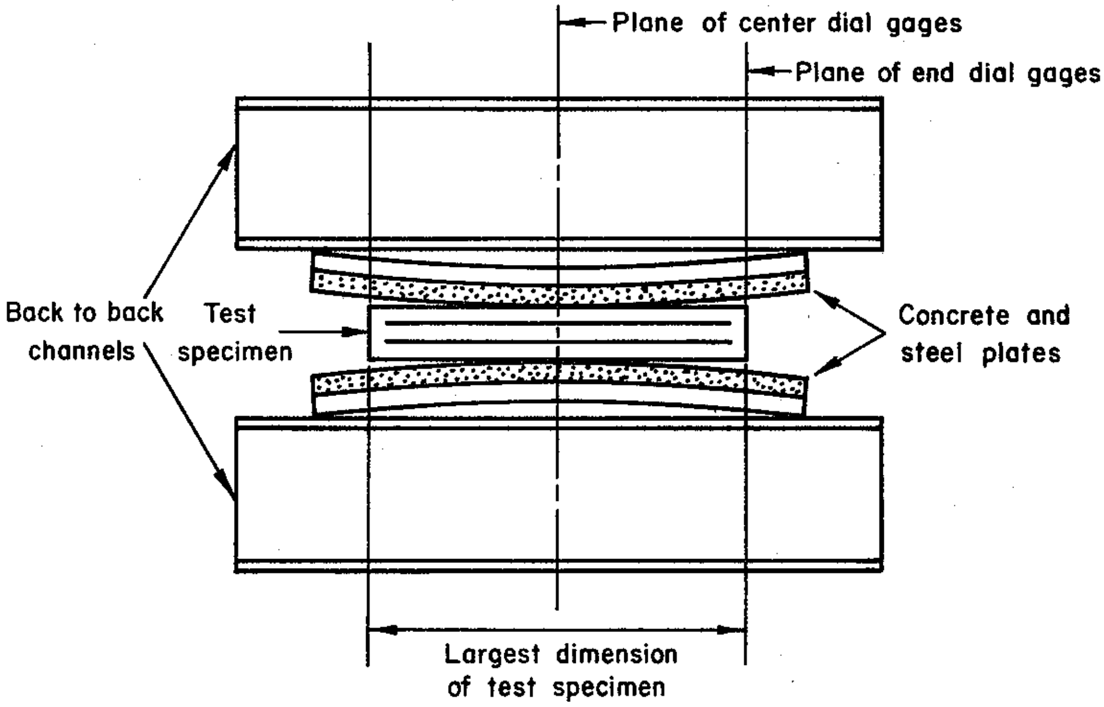
## B. Details of Data Acquisition in Compressive Tests of Large Pads

The Battelle researchers have pointed out that variations in test methods can result in significant variations in compressive stress/strain data[3]. This was found to be particularly true when testing relatively large pads, say, 200 square inches and larger. In testing these large pads, there are two potential problem areas which must be given careful consideration: (1) To apply the compressive load in a manner which simulates the loading in a bridge structure; and (2) To assure that the compressive deflections measured actually represent the deflections of the test pad.

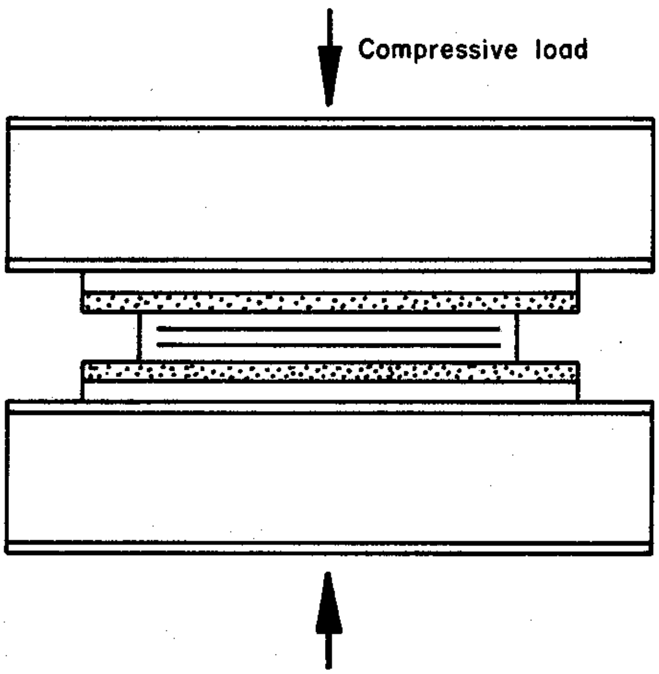
In a bridge structure, bearing pads are normally squeezed between two large masses of concrete or steel whose rigidity is infinite relative to the bearing pad's rigidity. Also, construction techniques are such that the surfaces of these large masses are normally a flat plane where they bear against the pad. Efforts to simulate these conditions in this testing program were not fully successful. Early in the testing program, the two 4-1/2" x 24" x 48" concrete and steel plates shown in Figure 3 were fabricated to provide the necessary rigidity. Although the concrete was heavily reinforced and connected to the steel plates by shear connectors, these composite plates tended to bend significantly when used to load a relatively large pad. The four sets of back to back channels shown in Figure 3 were then fabricated to effectively increase the bending stiffness of the composite plates. The use of the back to back channels provided sufficient rigidity, but eventually revealed a second problem. Because of previous loading history, the composite plates were permanently warped about 1/16 inch as measured along the length of the plates.

The effect of this warpage is illustrated schematically in Figure 1A. As the compressive stress is increased from zero to about 200 psi, depending on pad size, the center dial gages represent incremental pad deflections, while the end dial gages reflect primarily the bending of the composite plates. Above about 200 psi, the composite plates are flat against the pads and the incremental readings of the end dial gages actually represent incremental pad deflection.

The data from a typical test is shown in Figure 2A illustrating the substantially higher deflections of the end gages at compressive stress levels below 200 psi. However, above 200 psi the slopes of the two stress/strain curves become equal indicating that the compressive strain is applied uniformly throughout the pad's plan area. Based on these observations, the data obtained from the end dial gages has been disregarded because it does not represent pad deflections at the lower stress levels. The data presented in the body of this report is based on only the center gages because this data is considered representative of actual pad deflections. The decision to use only the center gage data is supported by the good correlation with data obtained from tests of smaller pads where plate bending did not occur. This correlation is illustrated in Figures 9 and 10.




CONDITIONS PRIOR TO LOADING




CONDITIONS ABOVE 200 PSI COMPRESSION

Figure IA THE EFFECT OF PLATE WARPAGE ON COMPRESSIVE TEST DEFLECTION DATA

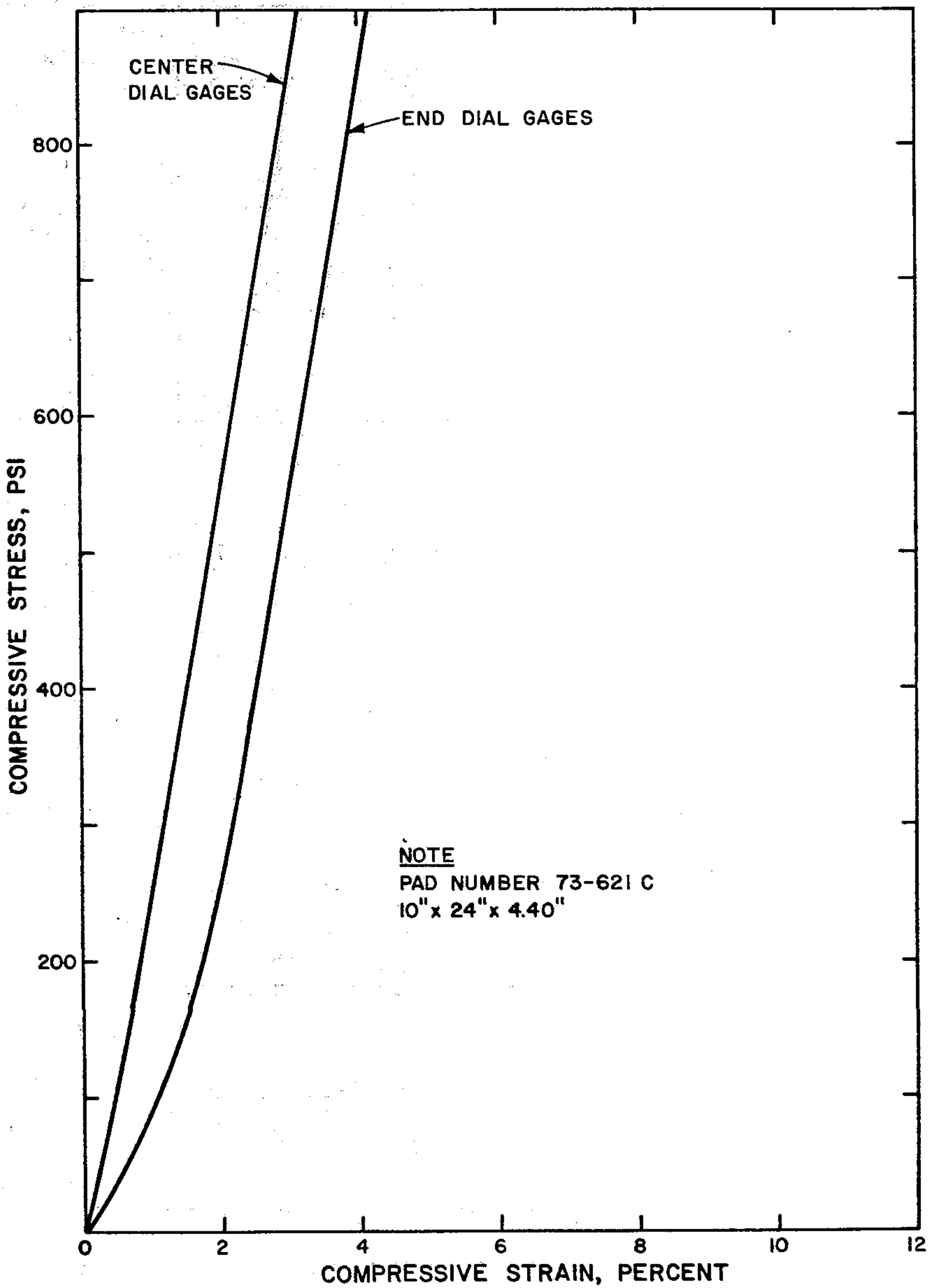



Fig. 2A COMPARISON OF DATA FROM CENTER DIAL GAGES VERSUS END DIAL GAGES

If future research is contemplated for determining the compressive stress/strain behavior of large bearing pads, careful consideration should be given to applying compressive loads to the test pads by a rigid mass with flat bearing surfaces. Large portable reinforced concrete blocks with surfaces poured against flat steel plates should be considered for this purpose.

Another area which should be carefully considered in future research is the means by which pad deflections are measured. As noted in Section IV.B., the linear variable differential transformer, LVDT, in the testing machine was used to measure the compressive deflections of only relatively small pads. This method is satisfactory for small pads because the deflection of the testing machine is very small compared to the deflection of the pad. However, as the plan area of the test pad increases, (1) the compressive deflection of the pad decreases due to the higher shape factor, and (2) the deflection of the testing machine increases due to the higher loads. For example, when testing a 4.40" x 24" x 40" fiberglass reinforced pad in compression, the incremental displacements of the testing machine were approximately three times the corresponding displacements of the pad. The magnitude of this discrepancy will, of course, vary depending on test conditions such as pad thickness and testing machine characteristics, but future research should possess assurance that measured deflections represent actual pad deflections.

## C. 1973 Standard Specifications for Steel or Polyester Reinforced Pads

**51-1.12H Elastomeric Bearing Pads.**—Elastomeric bearing pads shall conform to the requirements in these specifications and the special provisions.

Pads ½ inch and less in thickness may be either laminated or all elastomer.

Pads over ½ inch in thickness shall be laminated.

Laminated pads shall consist of alternate laminations of elastomer and metal or elastomer and fabric bonded together.

The outside laminations shall be metal or fabric. The outside and edges of metal laminations shall be coated over with elastomer not more than ⅛ inch in thickness.

Laminations of elastomer shall be ½ inch ± ⅛ inch in thickness. Variation in thickness of an individual elastomer lamination shall not exceed ⅛ inch within the width or length of a pad and the variation in thickness of all elastomer laminations within a pad shall be such that each metal or fabric lamination will not vary by more than ⅛ inch from a plane parallel to the top or bottom surface of the pad.

The total out to out thickness of a pad shall not be less than the thickness shown on the plans nor more than ¼ inch greater than that thickness. Variation of total thickness within an individual pad shall not exceed ⅛ inch.

Pads containing metal laminations shall be full molded. Pads of all elastomer or with fabric laminations may be cut from large sheets. Cutting shall be performed in such a manner as to avoid heating of the material and to produce a smooth edge with no tears or other jagged areas and to cause as little damage to the material as possible.

Corners and edges of molded pads may be rounded at the option of the Contractor. Radius at corners shall not exceed ⅜ inch, and radius of edges shall not exceed ⅛ inch.

The bond between elastomer and metal or fabric shall be such that, when a sample is tested for separation, failure shall occur within the elastomer and not between the elastomer and metal or fabric.

Metal laminations shall be rolled mild steel sheets not less than 20-gage in thickness.

Fabric laminations shall be either (1) a long chain synthetic polymer containing at least 85 percent of polyester from ethylene glycol and teraphthalic acid or (2) a long chain synthetic polymeric amide from hexamethylene diamine and adipic acid. Each ply of fabric shall have a breaking strength of not less than 700 pounds per inch of width in both directions. Fabric laminations shall be single ply at top and bottom surfaces of the pad and either double ply or double strength within the pad.

The sole polymer in the elastomeric compound shall be neoprene and shall be not less than 60 percent by volume of the total compound.

The elastomer, as determined from test specimens, shall conform to the following:

| Test | ASTM Designation | Requirement |
|---|---|---|
| Tensile strength, psi | D 412 | 2,250 Min. |
| Elongation at break, percent | D 412 | 350 Min. |
| Compression set, 22 hrs. at 158° F., percent | D 395 (Method B) | 25 Max. |

| | | |
|---|---|---|
| Tear strength, pounds per inch | D 624 (Die C) | 180 Min. |
| Hardness (Type A) | D 2240 | 55 ± 5 |
| Ozone resistance 20% strain, 100 hrs. at 100° ± 2° F. | D 1149 (except 100 ± 20 parts per 100,000,000) | No cracks |
| Low temperature stiffness, Young's Modulus at —30° F., psi | D 797 | 5,000 Max. |
| Low temperature brittleness, 5 hrs. at —40° F. | D 736-54T | Passed |

After accelerated aging in accordance with ASTM Designation: D 573 for 70 hours at 212° F. the elastomer shall not show deterioration changes in excess of the following:

| | |
|---|---|
| Tensile strength, percent | ± 15 |
| Elongation at Break, percent | — 40 (but not less than 300% total elongation of the material) |
| Hardness, points | + 10 |

Specimens tested in accordance with Test Method No. Calif. 663 for 10,000 cycles at 800 pounds per square inch and ½ t (pad thickness) translation, shall show no indication of deterioration of elastomer or bond between elastomer and metal or fabric reinforcement laminations.

The Contractor shall furnish to the Engineer a certification by the manufacturer that the elastomer, and fabric (if used), in the elastomeric bearing pads to be furnished conforms to all of the above requirements. The certification shall be supported by a certified copy of the results of tests performed by the manufacturer upon samples of the elastomer and fabric to be used in the pads.

Test specimens for tensile strength, elongation, tear strength, and ozone resistance will be taken from production run pads by the Engineer, and will be prepared for testing by cutting and grinding. The Engineer will take a sample pad not less than 6 inches by 12 inches in size for testing from each lot of pads or batch of elastomer to be furnished, whichever results in the greater number of samples. The samples will be selected at random at the point of manufacture or, at the option of the Contractor, at the job site. Samples taken at the job site shall consist of complete pads as detailed on the plans, and the Contractor shall furnish additional complete pads to replace those taken for testing. Pads shall be available for sampling 3 weeks in advance of intended use. All sample pads for testing shall be furnished by the Contractor at his expense.

Where elastomeric bearing pads over ½ inch in thickness are shown on the plans, such pads may be manufactured as a molded laminated pad, or at the option of the Contractor, may be made up by stacking individual laminated pads. When laminated pads are stacked, their contact surfaces shall be cleaned prior to stacking and a positive method shall be used to hold the individual pads in the stack in proper alignment.

State of California
Department of Public Works
Division of Highways

MATERIALS AND RESEARCH DEPARTMENT

Test Method No. Calif. 663-B
April 2, 1973
(9 pages)

# TESTING OF BRIDGE BEARING PADS

## PART I. DETERMINATION OF COEFFICIENT OF FRICTION AND FATIGUE LIFE

### Scope

The procedures to be used for the determination of the fatigue life and coefficient of friction or internal shear resistance of various bearing pad assemblies such as bronze, elastomeric, TFE (Teflon), etc., are described in this Part I.

### Procedure

**A. Testing Apparatus and Accessories**

1. Expansion bearing pad fatigue testing machine. (See photograph and schematic drawing, Figures I and II.)
2. Acetone
3. Stop watch
4. SR-4 strain indicator
5. 6-inch steel scale graduated in 1/100 of an inch.

**B. Test Record Form**

Use work card, Form HMR T-6028, for recording test data.

**C. Specimen Preparation**

1. Clean all test specimens and both platens so that they are free of any foreign substances such as dust, grit, moisture, etc., except for the lubricants used in conjunction with the bronze specimens such as oil, grease, etc. Cut the elastomeric specimens to size (standard size 6″ x 6″) and wipe clean. File smooth any rough edges on the bronze specimens and wipe clean. Use acetone to clean the bearing surfaces of TFE (Teflon) bonded specimens only.

**D. Test Procedure**

1. After the specimen has been centered on the lower platen of the fatigue machine, screw the eight platen leveling rollers far enough into the platen so that they do not contact the vertical guide plates.
2. Zero in the strain indicator.
3. Apply vertical load by operating valves #1 and #2.
4. Then adjust valve #6 to maintain the required pressure as read on gage #2.
5. At this time the loading platens should be parallel; check with steel scale. If loading heads are not parallel, unload and repeat the loading procedure.
6. Remove the "at rest" shims and screw the eight platen leveling rollers finger tight against the guide plates to maintain platen stability.
7. Operate the top loading platen using the following procedure:
   a. Start hydraulic pump (start button).
   b. Open valve #5 all the way and then adjust valve #4 to maintain the proper testing speed. Note: Valve #5 must be opened before speed can be adjusted by valve #4.
   c. Adjust the testing speed by the use of a stop watch.
   d. Measure the horizontal load by use of the SR-4 strain indicator.
   e. The pressure indicated on page #3 is controlled by valve #7. The function of valve #7 is to control the pressure applied to the horizontal ram.
8. At the end of the test period, stop and unload the machine by reversing the loading steps.

**E. Horizontal Force Measurements**

During the course of the test, record the strain gage readings to determine the horizontal force.

1. Take static coefficient of friction readings at the instant of impending motion or slip between the surfaces in question. For flexible backed TFE (Teflon) bearings, measure strain at the point of maximum displacement.
2. Obtain kinetic coefficient of friction readings by taking the average reading while surfaces are sliding. Do this in both directions of movement.

**F. Calculations**

$$f = \frac{F}{N}$$

Where:

F=Horizontal force due to friction or internal shear resistance (lbs).
N=Normal force (lbs).
f=Coefficient of friction
$f_s$ = static
$f_k$ = kinetic

Determine "F" from the strain gage indicator readings by use of calibration plot I (Figure III). Determine N from gage #2 (Figure II) by use of calibration plot II (Figure IV).

### REPORTING RESULTS

1. Report the following test results on test report Form HMR T-6028.
   a. Maximum static coefficient of friction.
   b. Average static coefficent of friction.
   c. Average kinetic coefficient of friction.
   d. Remarks concerning the specimen's appearance after completion of test, excessive wear, delamination, etc.

The "The maximum friction coefficient" as determined on Form HMR T-6028 is defined as the highest coefficient as averaged over any 50 cycles of the test.

The "Average friction coefficient" is defined as the average of at least 5 and not more than 10 readings taken between 2,000 and 8,000 cycles. These readings shall be taken at intervals of not less than 500 cycles apart.

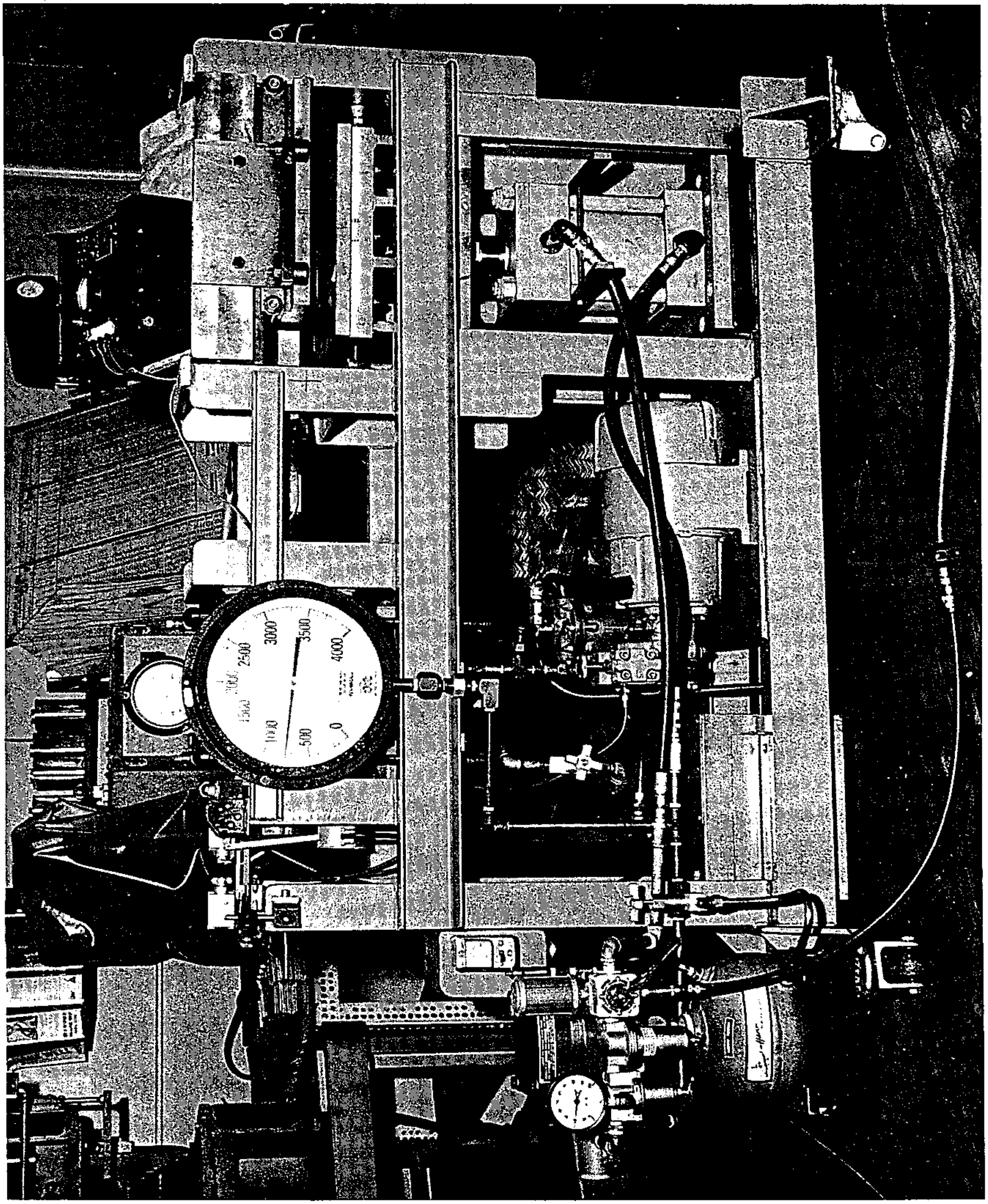


FIGURE I

# SCHEMATIC DIAGRAM OF FATIGUE TESTING MACHINE

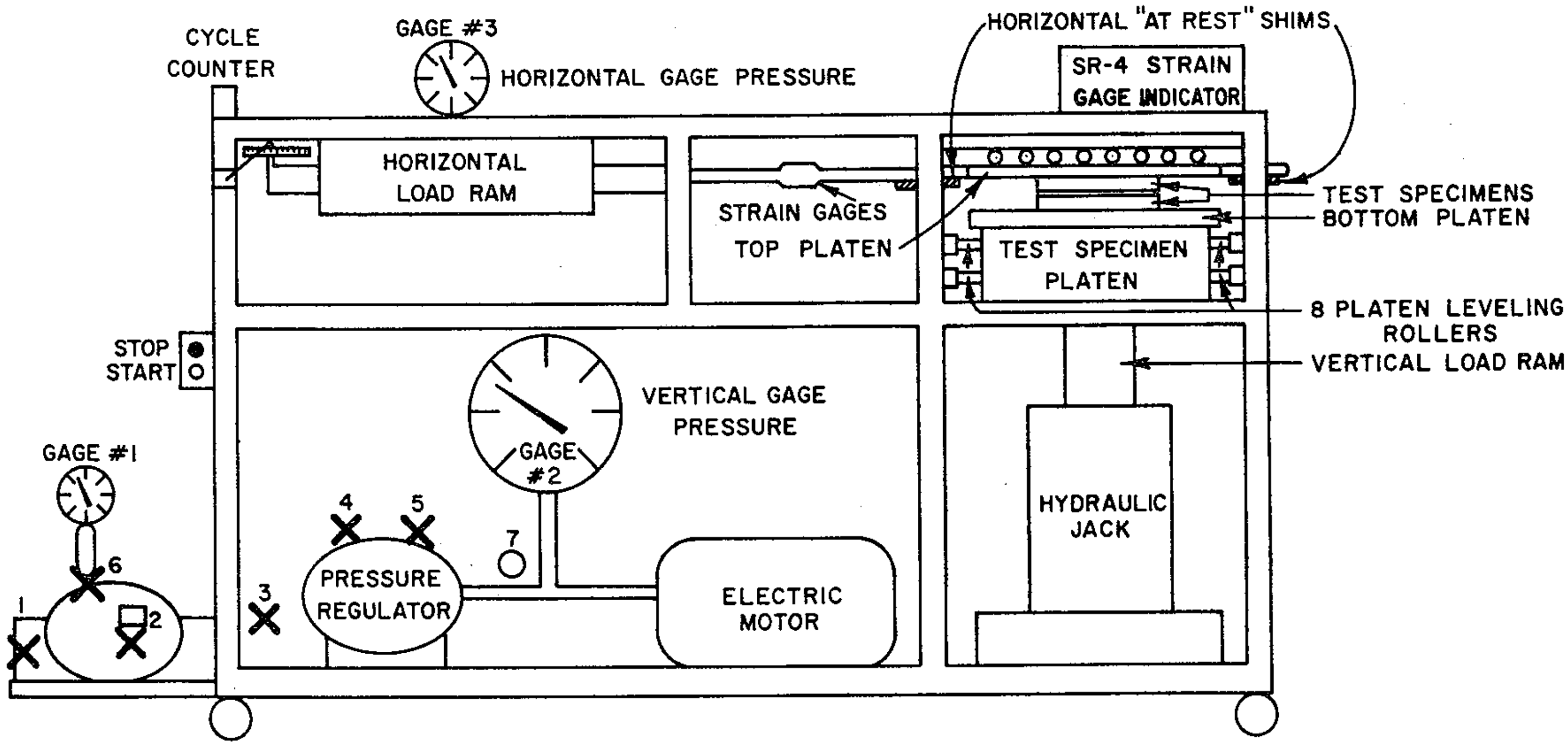



FIGURE II

# BEARING PAD FATIGUE TESTING MACHINE

## STRAIN GAGE CALIBRATION CURVE

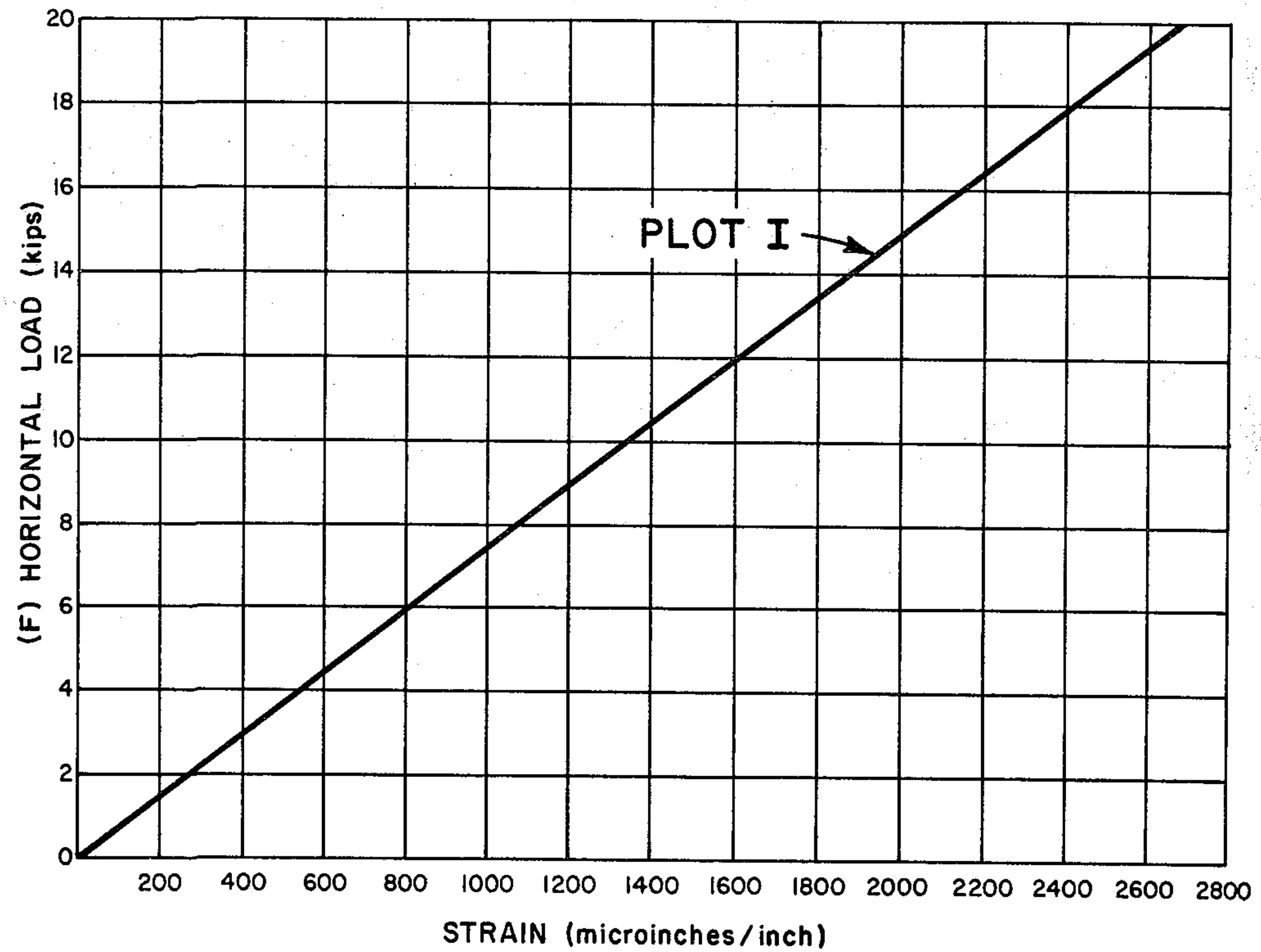



FIGURE III

## BEARING PAD FATIGUE TESTING MACHINE

### VERTICAL LOAD CALIBRATION CURVE

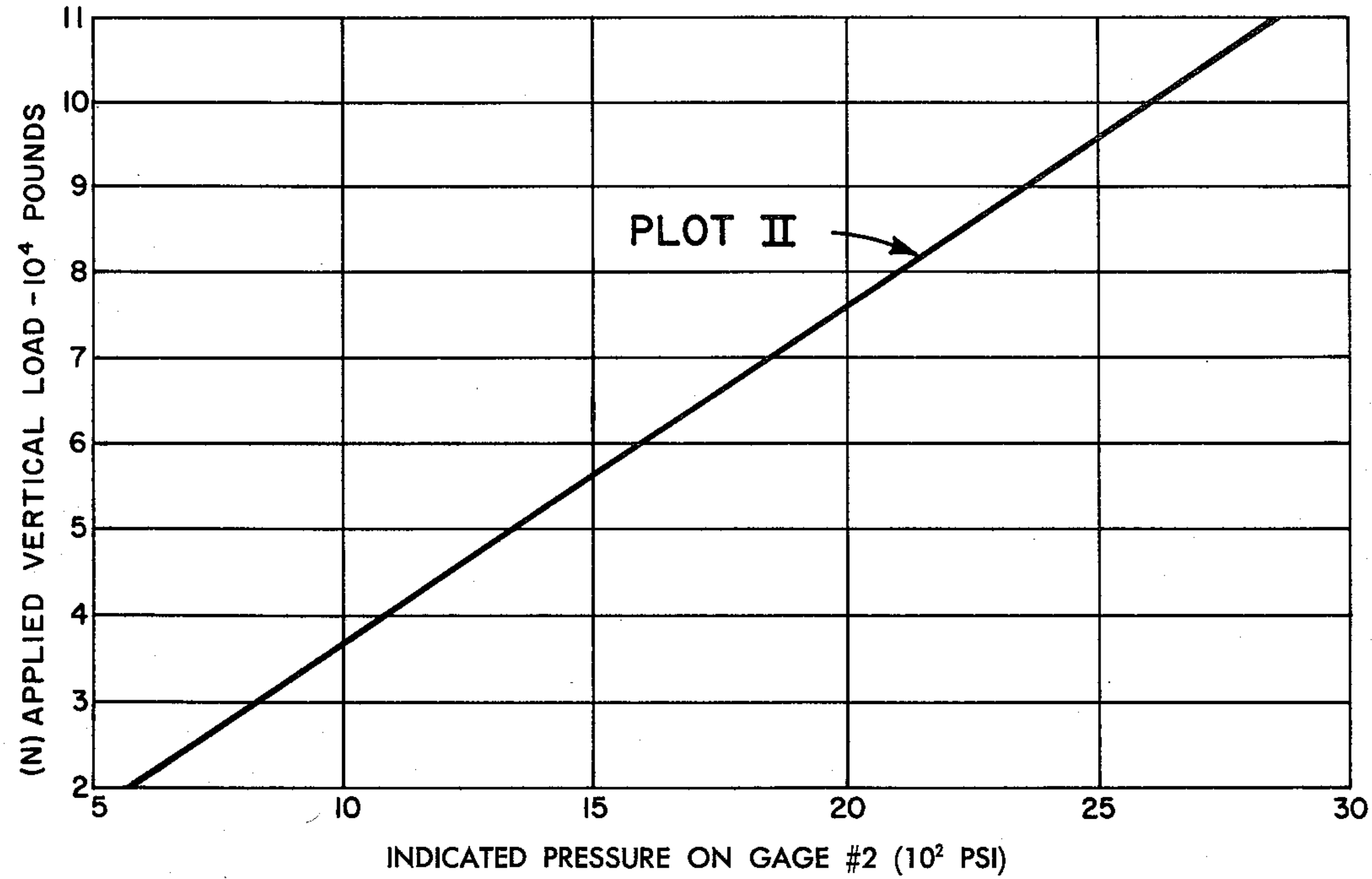



FIGURE IV

MATERIALS AND RESEARCH DEPARTMENT

# FATIGUE AND COEFFICIENT OF FRICTION TEST DATA SHEET

TYPE: ____________________

SIZE: ____________________

DATE: __________ LOAD: __________

STROKE: SPEED:

DRAWING OF SPECIMEN

| CYCLES | SPEED INCHES/ MINUTE | + READING | − READING | MOVING AVERAGE | GAGE PRESSURE | N KIPS | +f KIPS | −f KIPS | MOVING f KIPS | +u | −u | THICKNESS INCHES | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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HMR T-6028 (Orig. 11/66)

## PART II. DETERMINATION OF PEEL STRENGTH

### Scope

The procedures to be used in determining the peel strength of elastomer bonded to metal or fabric reinforcement for elastomeric bearing pads are described in this Part II.

### Procedure

**A. Test Apparatus and Accessories**

1. A testing machine which can measure loads up to 100 pounds with an accuracy of plus or minus one percent and a platen speed of 2 ± 0.2 inches per minute.

2. Rubber grips with jaws at least one inch wide. The grips shall be capable of firmly gripping the specimen without slippage during the testing.

3. A saw capable of cutting smoothly through elastomeric bearing pads with metal or fabric reinforcement.

**B. Specimen Preparation and Testing**

1. Cut a one inch section (full thickness) off one side of the bearing pad sample as shown in Figure V(a). The minimum length shall be six inches.

2. Cut the section into test specimens as shown in Figure V(b).

3. Initiate peeling by neatly cutting neoprene back to neoprene-reinforcement interface. See Figure V(c).

4. Initiate uniform peeling by pulling on specimen. Separate the specimen a sufficient distance to permit clamping in the grips of the machine.

5. Install the specimen in the grips of the testing machine as shown in Figure VI. Care should be used in installing the specimen symmetrically so that the tension is applied uniformly. The grips shall concentrically maintain the specimen in a vertical direction during testing.

6. Apply the load at a uniform rate of 2 ± 0.2 inches per minute for a distance of at least two inches.

7. Determine and record the peel strength in pounds per inch. Peel strength is defined as the average load recorded on the testing machine when the specimen is slowly and uniformly peeled without snagging or binding.

### Reporting of Results

Document results of tests with appropriate comments and notations on Form T-610. Report results in formal form (as complying or not complying with specifications) on Form T-6039.

## PART III. DETERMINATION OF THE PHYSICAL PROPERTIES OF BRIDGE BEARING PADS

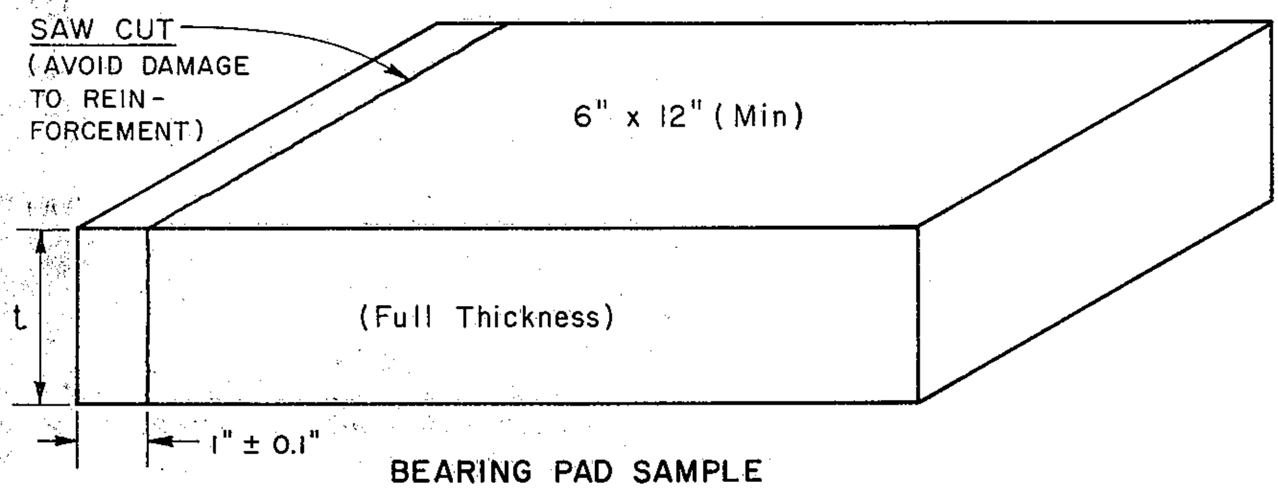
Except as shown in Part I and Part II, the other physical properties of bridge bearing pads shall be determined in accordance with the procedures as outlined in the appropriate American Society for Testing and Materials (ASTM) specifications or the American Association of State Highway Officials (AASHO) specifications, as specified in the Standard Specifications of the Division of Highways.

**REFERENCE**

A California Method
California Standard Specifications

End of Text on Calif. 663-B

# SPECIMEN PREPARATION




BEARING PAD SAMPLE
3/8" = 1"
(a)

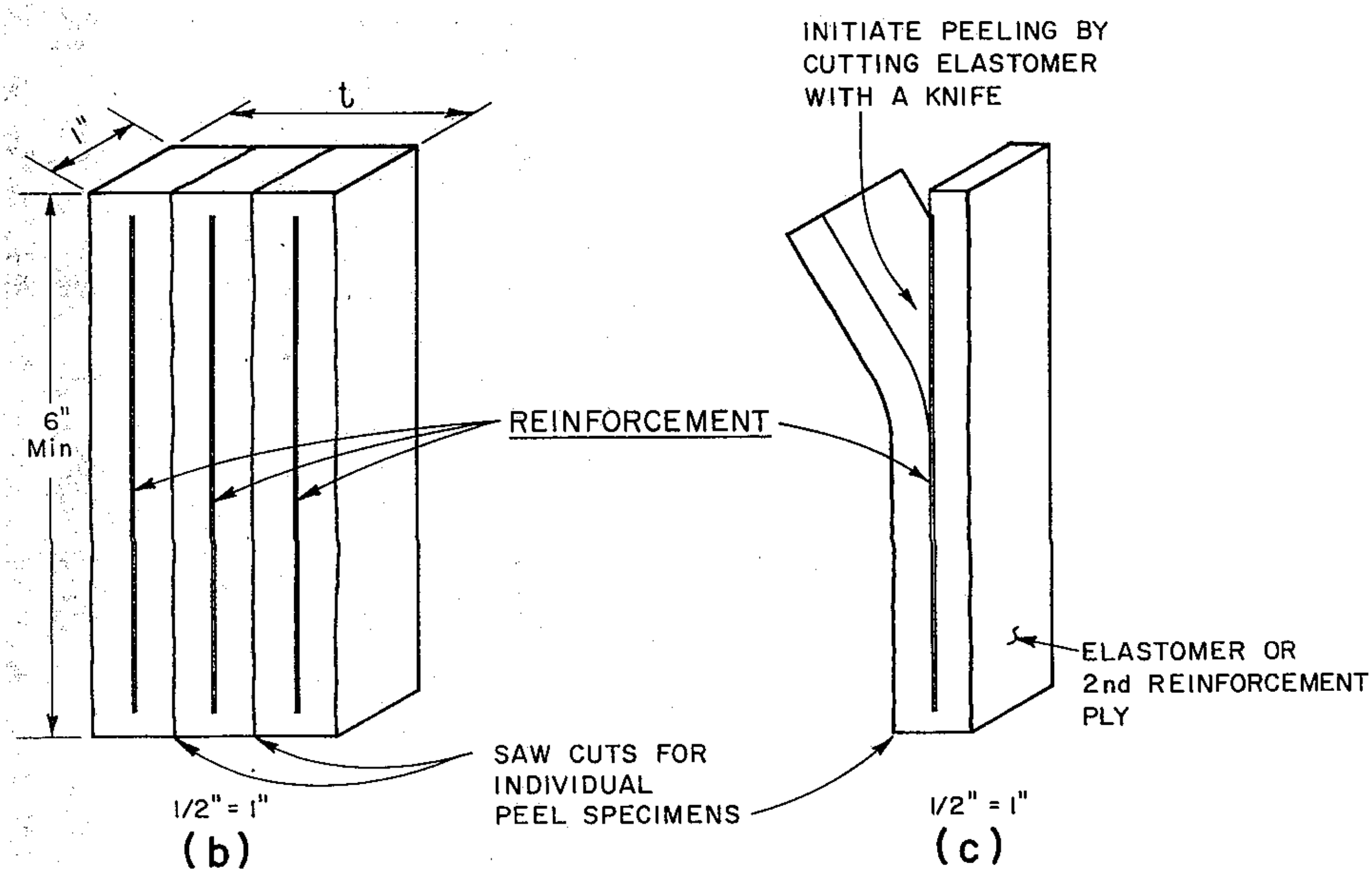



FIGURE V

# PEEL TEST

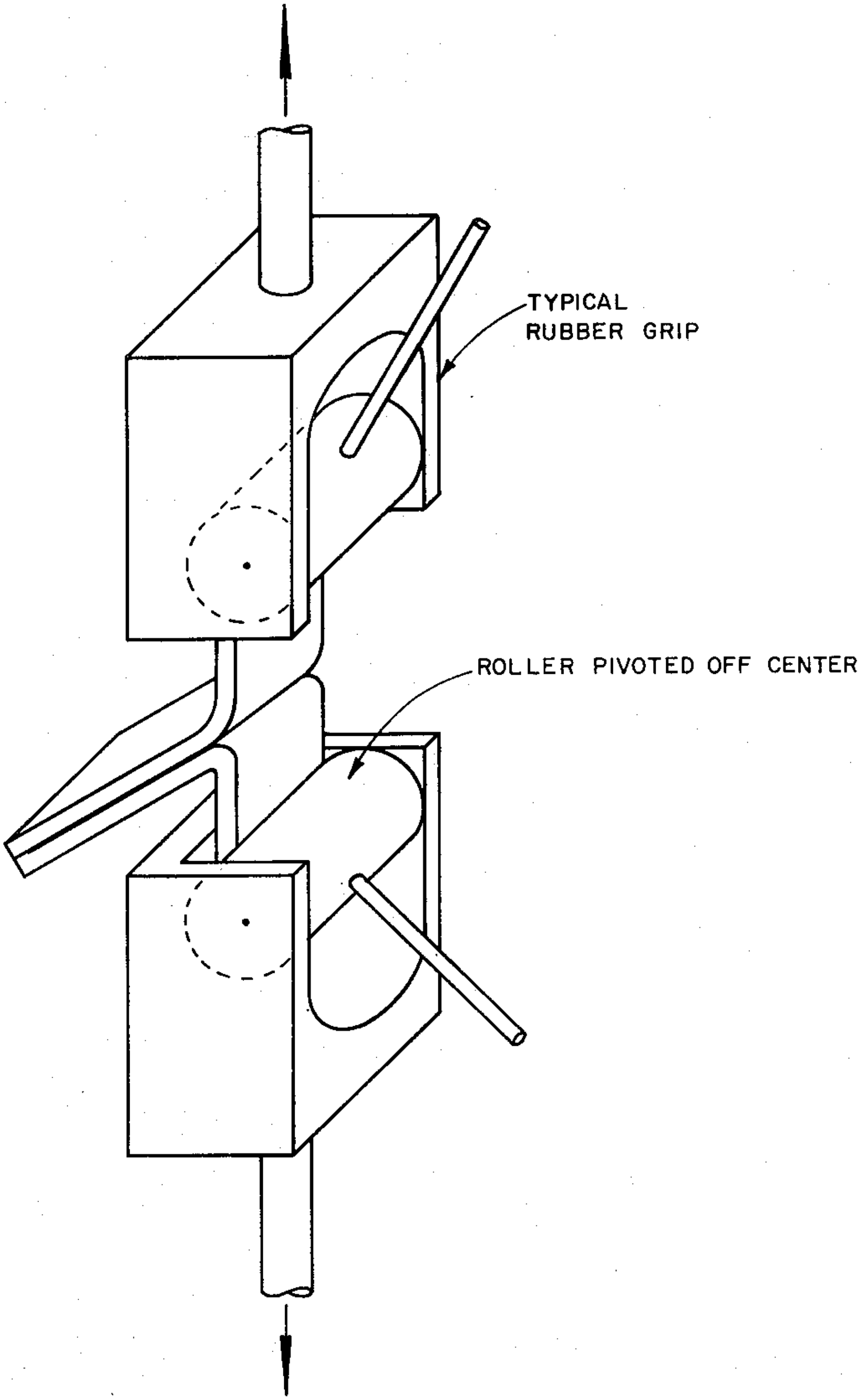



FIGURE VI

## E. 1975 Standard Specification for Steel or Fiberglass Reinforced Pads

51-1.12H Elastomeric Bearing Pads.---Elastomeric bearing pads shall conform to the requirements in these specifications and the special provisions.

Pads 1/2 inch or less in thickness may be either laminated or all elastomer. Pads over 1/2 inch in thickness shall be laminated. Stacking of individually laminated pads to attain thicknesses over 1/2 inch will not be permitted; however, cold bonding of individual laminated pads will be permitted providing the bond between the pads has a minimum peel strength of 20 pounds per inch as required elsewhere in this specification.

Laminated pads shall consist of alternate layers of elastomer and metal or fabric reinforcement bonded together. The top and bottom layers of reinforcement shall be uniformly covered with a maximum of 1/8 inch of elastomer. The edges of metal reinforcement shall be fully coated with elastomer not more than 1/4 inch in thickness.

Laminated pads shall have reinforcement every 1/2 inch through the entire thickness. The reinforcement shall be parallel to the top and bottom surfaces of the pad. Variations in the location of the reinforcement in excess of 1/8 inch from its theoretical location shall be cause for rejection. The total out to out thickness of a pad shall not be less than the thickness shown on the plans nor more than 1/4 inch greater than that thickness.

Pads of all elastomer or with fabric reinforcement may be cut from large sheets. Cutting shall be performed in such a manner as to avoid heating of the material and to produce a smooth edge with no tears or other jagged areas and to cause as little damage to the material as possible.

The bond between elastomer and metal or fabric shall be such that when a sample is tested for separation, it shall have a minimum peel strength of 30 pounds per inch when tested in accordance with Test Method No. Calif. 663.

Metal reinforcement shall be rolled mild steel sheets not less than 20 gage in thickness.

Fabric reinforcement shall be woven from 100 percent glass fibers of "E" type yarn with continuous fibers. The minimum thread count in either direction shall be 25 threads per inch. The fabric shall have either a crowfoot or an 8 Harness Satin weave. Each ply of fabric shall have a breaking strength of not less than 800 pounds per inch of width in each thread direction when 3 inch by 36 inch samples are tested on split drum grips. Fabric reinforcement shall be single ply at top and bottom surfaces of the pad and double ply within the pad. The bond between double plies shall have a minimum peel strength of 20 pounds per inch.

The sole polymer in the elastomeric compound shall be neoprene and shall be not less than 60 percent by volume of the total compound.

The elastomer, as determined from test specimens, shall conform to the following:

| Test | ASTM Designation | Requirement |
|---|---|---|
| Tensile strength, psi | D 412 | 2,250 Min. |
| Elongation at break, percent | D 412 | 350 Min. |
| Compression set, 22 hrs.at 158°F., percent | D 395 Method B) | 25 Max. |
| Tear strength, pounds per inch | D 624 (Die C) | 180 Min. |
| Hardness (Type A) | D 2240 (with 2 kg.wt.) | 55±5 |
| Ozone resistance 20% strain, 100 hrs.at 100°±2°F. | D 1149 (except 100 ± 20 parts per 100,000,000) | No cracks |
| Low temperature stiffness, Young's Modulus at -30°F.,psi | D 797 | 5,000 Max. |
| Low temperature brittleness, 5 hrs.at -40°F. | D 736-54T | Passed |

After accelerated aging in accordance with ASTM Designation: D 573 for 70 hours at 212°F. the elastomer shall not show deterioration changes in excess of the following:

| | |
|---|---|
| Tensile strength, percent | -15 |
| Elongation at Break, percent | -40 (but not less than 300% total elongation of the material) |
| Hardness, points | +10 |

Specimens tested in accordance with Test Method No. Calif. 663 for 10,000 cycles at 800 pounds per square inch and 1/2 t (t = total thickness of elastomer) translation, shall show no indication of deterioration of elastomer or bond between elastomer and metal or fabric reinforcement laminations. The testing speed will not exceed 4 1/2 inches per minute.

The Contractor shall furnish to the Engineer a certification by the manufacturer that the elastomer, and fabric (if used), in the elastomeric bearing pads to be furnished conforms to all of the above requirements. The certification shall be supported by a certified copy of the results of tests performed by the manufacturer upon samples of the elastomer and fabric to be used in the pads.

Test specimens for tensile strength, elongation, tear strength, peel strength, and ozone resistance will be taken from production run pads by the Engineer, and will be prepared for testing by cutting and grinding.

A fabric sample not less than 36 inches by 45 inches shall be submitted for testing from each new lot of fabric used in manufacturing bearing pads. A sample pad not less than 6 inches by 12 inches in size shall be submitted for testing from each lot of pads or batch of elastomer to be furnished, whichever results in the greater number of samples. The samples will be selected at random at the point of manufacture or, at the option of the Contractor, at the job site. Samples taken at the job site shall consist of complete pads as detailed on the plans, and the Contractor shall furnish additional complete pads to replace those taken for testing. Pads shall be available for sampling 3 weeks in advance of intended use. All sample pads for testing shall be furnished by the Contractor at his expense.